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AND

Stratigraphic Occurrence of *Lituyapecten* in Alaska

GEOLOGICAL SURVEY PROFESSIONAL PAPER 354–J, K

MacNeil and Miller—DESCRIPTION AND OCCURRENCE OF *LITUYAPECTEN* FROM ALASKA AND CALIF.—Geological Survey Professional Paper 354–J, K

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SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 354-J, K

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1961

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

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By F. STEARNS MACNEIL

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New Miocene and Pliocene species from Alaska show the relation of a known unique Miocene species from Alaska to previously known Pliocene species from California, and a new subgenus is proposed for them

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LITUYAPECTEN (A NEW SUBGENUS OF *PATINOPECTEN*) FROM ALASKA AND CALIFORNIA

By F. Stearns MacNeil

ABSTRACT

A new subgeneric name, *Lituyapecten*, is proposed under the genus *Patinopecten* (used as a subgenus of *Pecten* by some authors) to include a small but characteristic group of large pectinids having, usually, frill-like lamellae on the ribs of its left valve.

Of unknown origin, the subgenus appears first in early Miocene (or possibly very late Oligocene) beds of Alaska. It inhabited Alaska throughout Miocene and into Pliocene time, spreading southward into California in the Pliocene; its last survivors in the California Pliocene may be younger than its last known representatives in Alaska.

Three previously described species are included in *Lituyapecten; yakatagensis* Clark, *purisimaensis* Arnold, and *dilleri* Dall; *coosensis* Shumard may be an aberrant member. Three new species are described; *P.* (*L.*) *poulcreekensis* MacNeil, *lituyaensis* MacNeil, and *falorensis* MacNeil. An unnamed possible subspecies of *poulcreekensis* is also recognized.

The subgenus is believed to comprise two stocks, the *yakatagensis* stock (*yakatagensis, lituyaensis, falorensis*, and *purisimaensis; coosensis* may be an atypical member), and the *dilleri* stock (*poulcreekensis* and *dilleri*). The last representatives of both stocks appear to have penetrated the farthest south; *P.* (*L.*) *falorensis* is known as far south as central California where it occurs in the Purisima formation; *P.* (*L.*) *dilleri* is known in the Pliocene of northern Lower California, Mexico.

INTRODUCTION

This study was prompted by a collection made by D. J. Miller in the summer of 1958 of some exceptionally well-preserved material from Yakataga Reef in the Yakataga district, and from Cenotaph Island in Lituya Bay, Alaska. After preparing this material it was realized that some large *Patinopecten* in it were worthy not only of description in themselves, but they shed new light on the internal relation of a conspicuous but poorly known group of *Patinopecten* occurring in the late Tertiary of both Alaska and California. Accordingly, a restudy was made of similar forms in older Alaskan collections as well as of related forms in California. With one exception the specimens figured here from Alaska are from the collections of the U.S. Geological Survey; they will be deposited in the U.S. National Museum. One specimen from the collection of the California Academy of Sciences is figured. The collections of both the Academy and the University of California at Berkeley were used in listing the occurrences of species. None of the specimens from Alaska illustrated here has been figured previously. The holotype of *Pecten* (*Patinopecten*) *yakatagensis* Clark, the only Alaskan species for which an illustration was available, is a poor specimen and is not refigured.

Related species in California Pliocene formations were studied in connection with the Alaskan species. Specimens of these species in the collections of both the University of California and Stanford University are illustrated here. These include the holotype of *Patinopecten* (*Lituyapecten*) *falorensis* MacNeil, a specimen figured previously as "*Pecten oregonensis* Howe var." by Manning and Ogle (1950, pls. 6, 7), some specimens of the same species from the Purisima formation, and what is believed to be one of the best specimens known of *Patinopecten purisimaensis* Arnold.

Most of the material from Alaska occurs as soft shell in fine-grained hard rock. Complete free specimens are rare and in collecting fracture takes place most commonly through the shell material, leaving part of the shell on the internal mold and part on the external mold, Most of the rock is noncalcareous, and it was found that molds having good detail could be obtained by dissolving away the shells in acid. Casts were made from these molds with liquid latex. With the exception of one specimen (pl. 42, fig. 4) that was collected as a mold filled with decaying vegetable material, presumably dissolved naturally by humic acids, all the rubber casts were obtained in this way.

SYSTEMATIC PALEONTOLOGY

Genus PATINOPECTEN Dall, 1898

Type: *Pecten caurinus* Gould. Recent, northern California to Alaska.

The genus *Patinopecten* is known only from northern Pacific waters; its southernmost record is in Lower

California. Numerous species, ranging in age from middle Tertiary to Recent, are known from both the North American and the Asiatic sides of the Pacific. Only two species survive; *P. caurinus* (Gould) from the United States and *P. yessoensis* (Jay) from Japan. The greatest number of species occurs in the Pliocene and late Miocene. The present paper describes the oldest known American species, a species occurring in beds of early Miocene or possibly late Oligocene age in Alaska. The first American species is a large form, which, together with its abrupt appearance, suggests that it is a migrant from elsewhere. Possibly the ancestral stock of *Patinopecten* is a still unknown pectinid in the beds of early Tertiary age of east Asia.

One of the earliest known Asiatic species is *Patinopecten yamasakii ninohensis* Masuda (1954, p. 13, figs. 1–3) from the Shiratori formation (early Miocene) of Japan. It is variable enough to foreshadow several subsequent types. Its antecedents, when they are found, should shed some light on the origin of *Patinopecten.*

Patinopecten is at present the most likely genus in which to place the species under consideration. However, it is by no means certain that *Lituyapecten*, the subgenus here proposed to include the pectens of the *P. yakatagensis* group, really is a subgenus of *Patinopecten.* We still know too little about the exact lines of descent within the highly complex pectinids to make definite statements.

Grant and Gale (1931, p. 188) say, "*Vertipecten* appears to be the connecting link between *Chlamys* and *Patinopecten.*" Elsewhere (p. 192) they remark

> This group of species [Patinopecten], although obviously closely related to *Chlamys* and to *Vertipecten*, is none the less, a rather distinct unit. It represents an evolutionary adaptation starting in the same irection as that taken by *Amusium;* but the external ribs did not become absolute, and hence the external lirae did not become sharp. The general shape, however, is the same. The shape of *Placopecten* is also similar. *Patinopecten* developed distinct external ribs, *Placopecten* retained but faint radial riblets on the exterior, while all that is left of the ribs of *Amusium* are the strengthened internal lirae. * * * *Amusium* is more closely related to *Janira*, and it is possible that its apparent relationship to *Patinopecten* is superficial, being a parallel adaptation to a somewhat similar environment.

There is strong reason for believing Grant and Gale are correct in assuming *Amusium* to be closely related to *Pecten* (*Pecten*) (=*Janira*). In fact, there is strong reason for believing typical *Pecten* (*Pecten*), *Amusium*, and *Pecten* (*Amussiopecten*) are coderivatives from a prototypical *Pecten* (*Pecten*). *Pecten* (*Amussiopecten*) seems to form a continuum between *Pecten* (*Pecten*) and *Amusium.*

However, the exact relation of *Patinopecten* to either *Vertipecten* or *Chlamys* is still rather obscure. *Vertipecten* seems to be closely related to some of the types included in *Chlamys*, but whether or not *Chlamys* as used by most modern authors is a monophyletic group is another matter. Certainly the left valve of the earliest known North American species of *Patinopecten* bears little resemblance to the left valve of coexisting species of *Vertipecten. Vertipecten* is unique in having its left valve more inflated than its right valve. It would be premature to say *Patinopecten* is not related to *Vertipecten* but it would be safe to say that if the two are related they must have diverged from each other at least as far back as early Tertiary time.

The known late Mesozoic and earliest Tertiary pectinids seem to indicate that the prototype of *Pecten* (*Pecten*) was derived from a *Camptonectes*-like ancestor. An *Amusium*-like stock was also differentiated at an early date, but it resembles true *Amusium* only in being smooth and probably was not the ancestor of *Amusium* s.s. The ontogeny of *Pecten* (*Pecten*), based on *P.* (*P.*) *jacobaeus* Lamarck, suggests that the prototypical stock may have been inequivalved but smooth. It may have been closely related to the primitive *Amusium*-like smooth forms. It developed ribs to produce *Pecten* (*Pecten*), and the ribs became secondarily obsolete but reinforced internally, along with flattening of both valves, to produce *Amusium* s.s. The more coarsely ribbed true pectens have well-developed rims along the sides of the internal projection of the interspaces between the ribs, presumably a stage in the development of the pairs of riblets on the inside of both *Pecten* (*Amussiopecten*) and *Amusium.* These paired internal ribs are probably a development independent of the single internal ribs of other externally smooth pectinids; still others are without internal ribs. *Patinopecten*, although resembling *Pecten* (*Amussiopecten*) externally, does not have paired internal ribs.

Very young shells of *Patinopecten caurinus* are nearly smooth with irregular radiating white lines in the shell, resembling some species of *Pseudamussium* and *Propeamussium.* They have a faint diagonal *Camptonectes*-like microsculpture. This, together with its lack of internal ribs, suggests a separation of the *Patinopecten* branch before the stabilization of *Pecten* (*Pecten*) and *Amusium.* Possibly *Patinopecten* came from intermediates between *Camptonectes* and *Pecten* (*Pecten*).

Left valves of most specimens of *Patinopecten caurinus* have delicate, evenly spaced raised concentric growth lines extending to the ventral margin; on some specimens there is a slight imbrication. Similar concentric growth lines are the characteristic microsculpture of the left valve of most species of *Pecten* (*Pecten*) and of *Pecten* (*Amussiopecten*). Some of the early true

Amusium may have had similar concentric growth lines, but the later species of *Amusium* have both valves smooth and polished. The group of *Patinopecten* under consideration has fine concentric growth lines on the early stages of the left valve, but the typical sculpture of the left valve of adults is characterized by lamellae or flanges which may extend entirely across the ribs or which may be divided into two series, one along each edge of the flat-topped ribs. The transition from the the juvenile to the adult sculpture may be abrupt or gradual. On some individuals the fine concentric growth lines persist in adults in the interspaces as well as on top of the ribs between the blunt spines or flanges.

No specimens of *Lituyapecten* yet observed show any suggestion of the imbricating microsculpture, resembling the surface of metal lath, that characterizes left valves of *Chlamys*, *Vertipecten*, *Fortipecten*, and some species of *Patinopecten* such as *P. yessoensis*, *P. propatulus* (Conrad), and *P. ibaragiensis* Masuda (1953), pls. 5, 6); imbricating microsculpture occurs rarely in small patches on specimens of *P. caurinus*. On the other hand, *P. coosensis* (Shumard) (see Trumbull, 1958, pls. 115–117), a species generally referred to *Patinopecten* s. s., has a concentric microsculpture, not an imbricating one.

It may be that *P. coosensis* is really a flangeless *Lituyapecten*, not a member of the *P.* (*Patinopecten*) *caurinus* group. In support of this, a flangeless variant of *P.* (*L.*) *yakatagensis* (pl. 45, fig. 3; pl. 46, fig. 5), whose left valve ribs are squared like those of *P. coosensis*, has only fine concentric growth lines all the way to the ventral margin. These two species also have a peculiar strong fold on the anterior ear of the left valve.

The origin of *Fortipecten* was discussed by Yabe and Hatai (1940, p. 153–155). Yabe and Hatai suggested that some Miocene *Patinopecten* might be the ancestor of this subgenus. Since their paper was written, a Miocene species has been described, *Patinopecten ibaragiensis* Masuda (1953, p. 44, pl. 5, figs. 1–5; pl. 6, figs. 1–5), which definitely seems to be the connecting link between *Patinopecten* and *Fortipecten*. I am inclined to regard *Fortipecten* as a subgenus of *Patinopecten* on the basis of this species. The genus *Patinopecten* would then embrace three subgenera: typical *Patinopecten*, *Fortipecten*, and *Lituyapecten*.

If an imbricating mocrosculpture is a primative character that persists in several lines of descent such as *Chlamys* (*Chlamys*), *Chlamys* (*Swiftopecten*), *Chlamys* of the *C. beringianus* group, *Vertipecten*, and *Patinopecten*), it is difficult to see why it is present in some typical *Patinopecten* and not in others. The microsculpture is developed in a layer that is readily decorticated, and it is only seen on exceptionally well-preserved specimens; sometimes only a small patch of it can be found. As far as is known, only concentric microsculpture is found in *Amusium*, *Pecten* (*Amussiopecten*, *Pecten* (*Pecten*), and *Patinopecten* (*Lituyapecten*).

It is entirely possible that *Patinopecten* inherited an imbricating microsculpture which, although persisting in *Fortipecten* and in some species of typical *Patinopecten*, was eliminated in some typical *Patinopecten* and in *Lituyapecten*. It is also possible that there was no persistence of this character in the phylogenetic lines connecting *Patinopecten* with *Vertipecten* and *Chlamys*, however short or long they might have been, and that this character was redeveloped in some branches of *Patinopecten*. At any rate, our present imperfect knowledge of pectinid phylogeny makes it impossible to settle the question.

Subgenus LITUYAPECTEN MacNeil, new subgenus

Type: *Patinopecten* (*Lituyapecten*) *lituyaensis* MacNeil, n. sp.

Diagnosis.—Shell medium large to very large; a right valve of the type species measures 8¼ inches in diameter; this size makes it one of the largest pectinids known. Outline ranges from subrounded to elliptical; long axis in some species is the height; in others, the length. Ears moderately large; byssal notch moderately strong to strong; anterior ear of right valve elongate, tends to become narrower, and curves ventrally in full grown adults; left valve ears more symmetrical, and anterior ear tends to develop a marginal fold (concave on the inside) opposite narrow ear of right valve. Ribs strong, and those of right valve moderately broad to broad; they tend to be undercut on sides, flat to rounded or irregular on top. Interspaces usually deep and round bottomed. Juvenile sculpture consisting of thin concentric raised lines.

Interstitial ribs may occur on either valve and they are usually beset by a single row of rounded frills or flanges. Right valve of *Lituyapecten* probably slightly more inflated than left valve. Crushing of known specimens makes it difficult to determine the relative inflation; certainly some known left valves more inflated now than right valves. Hinge plate relatively heavy and with a single nearly marginal groove in each of the left valve ears. Base of the hinge plate conspicuously swollen.

Discussion.—The subgenus is founded primarily on the left-valve sculpture. The ribs are moderately narrow to wide and rounded to flat topped. The juvenile sculpture consists of raised concentric growth lines that are fine and evenly spaced; they are similar to those normally covering the entire valve of *P. caurinus*.

The adult sculpture of *Lituyapecten* consists of sharply raised flanges or lamellae, which may be single or divided into two or more rows of segments.

I am indebted to Mrs. Ellen Trumbull, of the U.S. Geological Survey for a photograph of an unusually well-preserved specimen of *Patinopecten propatulus* (Conrad) from the Astoria formation (Miocene) of Oregon, a specimen which she will figure in a forthcoming paper. This specimen has several patches of imbricating microsculpture preserved. In addition, it has small frill-like flanges very close to the beak on three or four of the posterior ribs of the left valve. They are closer to the beak than I have seen them on other species having similar flanges, and they appear to have died out at the stage of growth at which they normally appear in other species. This specimen contains the only combination of imbricating microsculpture and frill-like flanges I have seen. On the basis of the frills alone, *P. propatulus* might appear to belong to *Lituyapecten*, even though the frills occur at a different growth stage than is common. I am inclined to believe that the juvenile frills on *P. propatulus* indicate that typical *Patinopecten* and *Lituyapecten* are closely related after all, something that I did not feel I could say positively from other species. Possibly *P.* (*Patinopecten*) and *P.* (*Lituyapecten*) diverged from each other in Oligocene time. *P. propatulus* certainly seems to be a typical *Patinopecten*, whereas I believe *coosensis* is an aberrent *Lituyapecten*.

Clark (1932, p. 808) in his description of *Pecten* (*Patinopecten*) *yakatagensis* said: "*Pecten yakatagensis* of all the species referable to the subgenus *Patinopecten* is unique. * * * It is very possible that *Pecten yakatagensis* should be placed in a new section." The new subgeneric name, *Lituyapecten*, is here proposed to include the species of *Patinopecten* having one to several rows of frill-like flanges on the ribs of the left valve.

Two groups of species are included under *Lituyapecten*, the *Patinopecten dilleri* group and the *Patinopecten yakatagensis* group. The *P. dilleri* group usually has subrounded ribs on the left valve and single flanges continuous across the ribs; rarely the flanges may be divided on one or two of the central ribs with the disconnected segments of the flanges alternating. In the *P. yakatagensis* group the flanges are broken up into two or more well-defined series located on ribs, which at least in full grown adults tend to be broad and flat topped. Two rows of short spinelike flanges, one along each side of flat-topped ribs, is the most common condition. However, the distinction of the flanges as single or multiple rows is sharp only in the Pliocene species, the last-known members of the group. The earliest known members are irregular in the division or nondivision of the flanges and in the distance of separation; the same specimen may have single or divided flanges on different ribs, or on different parts of the same rib. Thus, while the end members of these two groups may seem quite distinct, the earliest representatives indicate that they had a common ancestry and that the characters which distinguished their last-known representatives were characters of no more than individual variation in their earliest known representatives.

Lituyapecten commonly has large barnacles on its left valve, but none have been observed on right valves. (See pl. 37, fig. 7; pl. 42, fig. 3; pl. 43, figs. 1, 4.) Presumably it rested on its right valve. If they were active, specimens with large barnacles must have had their activity impeded; some barnacles on Alaskan specimens have bases measuring over 30 millimeters. The Geological Survey collection contains a Recent specimen of *Patinopecten* (*Patinopecten*) *caurinus* whose right valve is clean but whose left valve is covered by barnacle bases. Schools of this species are believed to move from location to location periodically.

As far as is known, *Lituyapecten* is typically North American. The known species are all from Alaska and California; apparently it never invaded Asiatic waters. It ranges from early Miocene, possibly late Oligocene, to late Miocene, possibly early Pliocene in Alaska. The California occurrences are Pliocene.

Patinopecten (Lituyapecten) poulcreekensis MacNeil, n. sp.

Plate 35, figures 1–6; plate 36, figures 1, 2(?), 3, 4, 6, 7; plate 38, figure 2

Shell moderately large, suborbicular; valves probably both moderately inflated, right valve possibly more so (inflation varies in specimens at hand, probably owing to crushing); shell of medium to above medium thickness. Dorsal margins straight to weakly concave; dorsal margins low and have a poorly defined submarginal slope. No visible denticles along margin of byssal sinus. Dorsal margin of ears straight. Ears moderately large; byssal sinus moderately deep and large; ears sculptured by strong radial riblets (about six) which are made scaly or frilled by the strongly upturned edges of closely set growth lines, the scaliness being strongest on the ribs; posterior ears of both valves have concave terminal margin with hinge line shorter than base of ear; anterior ear of left valve has convex terminal margin. Both valves with about 22 strong radial ribs and 1 or 2 additional minor ribs at both ends of valve; ribs of right valve more squared and undercut; ribs of left valve more rounded; a few ribs partly to completely bifurcating, a median cleft on 1 or 2 ribs being rather common. Ribs of right valve broad and range from smooth and flat to irregular and bear 2 or 3 secondary radial ridges of moderate strength; central ribs smooth, but the terminal ribs at both ends may have weak frills along one or both sides or single frills extending entirely across them; interspaces have moderate to strong interstitial ribs which, when not decorticated, are strongly frilled. Left valve has regular closely set raised growth lines in early stages; growth lines change abruptly to a stage having raised frills or flanges, the earliest being single and continuous across the ribs or, at most, divided into two series by a median discontinuity; flanges on opposite sides are often staggered or alternating, especially when first appearing, but are more often at the same position in later stages. In full-grown adults, frills may range from a single row to 2 rows with very narrow separation to 4 rows formed by division of double rows. Interspaces also have a moderately strong, highly frilled midrib; a few interspaces have two such interstitial ribs. Frills fragile and easily decorticated; best examples obtained as latex impressions after acid preparation. Right-valve microsculpture not detected and presumably smooth.

Holotype, a right valve (USNM 563572), measures: diameter 113 mm, height 113 mm. Largest right valve on hand has a height of 145 mm, to which must be added a few more millimeters for wear. Paratype, USNM 563573.

This species has not been found outside of the Yakataga and Katalla districts, Alaska. It is known to occur abundantly only in the uppermost part of the Poul Creek formation at Yakataga Reef, although a few fragments of it are known from rocks of nearly the same age at a few other localities. If the supposed stratigraphic position of the youngest known specimen in the Katalla district is correct, it ranged into beds equivalent to the lowermost part of the Yakataga formation, and was presumably coexistent with the early members of *P.* (*L.*) *yakatagensis*. The specimen in question, an extreme variant, is figured on plate 35, figure 6. One specimen (pl. 36, fig. 2), while from an isolated locality in the Suckling Hills (USGS 15843) whose stratigraphic position is in some doubt (see, Miller, p. 242), is believed, nevertheless, to be the oldest specimen collected, and it may be the oldest *Patinopecten* yet collected from North America; a late Oligocene age is possible.

Patinopecten (*Lituyapecten*) *poulcreekensis* will be compared with *P.* (*L.*) *yakatagensis* under the discussion of the latter species.

The known relatives of *P.* (*L.*) *poulcreekensis* all occur in younger beds in Alaska and California. Nothing similar to it is yet known from equivalent beds elsewhere, and its ancestors and regional provenance are unknown.

Distribution.—Early Miocene, northern Gulf of Alaska region: Katalla formation (upper part), Katalla district; Poul Creek formation (uppermost part), Yakataga district, Alaska.

Type locality.—Uppermost part of the Poul Creek formation at Yakataga Reef, USGS loc. M-271.

Other occurrences.—Katalla formation, upper (?) part, USGS 15843 (float), USGS 15852. Poul Creek formation, USGS 17733, CAS 29261, ?29264.

Patinopecten (Lituyapecten) poulcreekensis MacNeil, subsp?

Plate 36, figure 5; plate 38, figure 5.

Two incomplete specimens from near the Poul Creek–Yakataga formation boundary, but whose exact formational position is not known, are unique in having some sculptural details like *P.* (*L.*) *poulcreekensis*, some sculpture intermediate between *P.* (*L.*) *poulcreekensis* and *P.* (*L.*) *yakatagensis*, and narrower and more numerous ribs, agreeing in this respect more with *P.* (*L.*) *yakatagensis*. They could well represent linear intermediates between the two species, but at the same time they are typical of neither. The earliest growth stage on one fragment shows it to have concentric raised growth lines like juveniles of *poulcreekensis* and *yakatagensis*. Interstitial ribs with moderately strong flanges are present in some of the interspaces, agreeing in this respect with *poulcreekensis*.

The prevalence in this form of single strong flanges completely crossing the ribs suggests that it may be ancestral to the *P.* (*L.*) *dilleri* group, of which group a fragment obtained high in the section in the Lituya Bay district is believed to be a member (pl. 45, fig. 4; right valves on pl. 41, figs. 4, 5).

This form is not being named at present, although with better preserved material it probably would be. It seems likely that this form and typical *P.* (*L.*) *poulcreekensis* had a common ancestry but are at least subspecifically distinct. If this form and the one from the Suckling Hills (pl. 35, fig. 6) were end members of the same population it would be variable indeed.

The largest fragment figured (CAS 29285) has a diameter of 118 mm, a fraction of the whole dimension.

Distribution.—Early Miocene, uppermost part of the Poul Creek formation or the lowermost part of the Yakataga formation, Yakataga district, Alaska.

Localities.—CAS 29285; USGS D341 (T).

Patinopecten (Lituyapecten) yakatagensis (Clark)

Plate 37, figures 1–7; plate 38, figures 4, 6; plate 39, figure 2; plate 41, figures 2(?), 3; plate 42, figure 3

Pecten (*Patinopecten*) *yakatagensis* Clark, 1932, Geol. Soc. America Bull., v. 43, no. 3, p. 807, pl. 15, fig. 8, pl. 16, fig. 1.

Shell of medium size, suborbicular; valves both moderately inflated; left valve possibly less inflated than right valve; shell moderately thin. Dorsal margins weakly concave, low with weak submarginal slope on left valve; right-valve ears swollen; this condition makes boundary between ears and disk a sharp, narrow groove. No byssal denticles. Dorsal margin of ears straight to ventrally depressed at the terminal ends. Ears moderately flat but moderately elongate; byssal sinus large and deep, wider than terminal projection of anterior ear of right valve; ears sculptured by weak to moderate radial riblets (about nine when developed all over the ear), which may be weakly beaded or nearly smooth; anterior ear of left valve tends to develop a marginal fold, and terminal edge of ear indented opposite the fold—the stronger the fold the deeper the indentation. Both valves normally have about 30 to 31 radial ribs, but some variants have no more than 26–28. Ribs of right valve moderately narrow and straight sided to slightly undercut, and top flattened, occasionally with a well-defined bifurcation of at least one rib; central ribs smooth; terminal ribs often with weak side denticles, especially on terminal sides. Ribs of left valve subrounded in juveniles but become flattened or have a median trough on top in adults, the sides developing well-defined denticles. Juvenile stage of left valve has raised concentric growth lines which continue in adults in interspaces and in concavity on top of ribs. Adult left-valve sculpture consists of frills or flanges on the ribs, most common condition being a division of frills into two rows, one on each side of the ribs; frills vary in size and in distance from each other; a less common variant has single frills completely crossing each rib, or the same specimen may have some ribs with single frills and some ribs with divided frills; a single specimen from the Poul Creek formation compared with this species has no frills, the raised concentric growth lines extending all the way to ventral margin. Interspaces rarely have an interstitial riblet, but one specimen, which has a good development of undivided flanges on main ribs, has frilled interstitial riblets in some interspaces. Right valves do not appear to have a raised concentric microsculpture.

Holotype (UC 30381) measures; diameter about 75 mm, height about 79 mm. One of the largest specimens (USNM 563590) with both dimensions complete measures 123 mm in diameter and 123 mm in height.

The typical form of this species is known only from the Yakataga formation and in an interval extending 300 to 3,700 feet above the base of the formation, although a possible variant of it was found in the uppermost part of the Poul Creek formation. The type (a poor specimen not refigured here) probably came from about 350 to 400 feet above the base of the formation. The typical form has a left valve similar to those figured on plate 37, figures 4 and 7, and plate 42, figure 3. It was characterized by a juvenile stage having fine concentric growth lines on the ribs and an adult stage having well-developed marginal flanges on the ribs separated by a median trough—the trough is sculptered by raised growth lines like those on the juvenile ribs. The ribs tend to be less raised and not as well defined in the advanced growth stages of large specimens. No specimens seen thus far from well up in the Yakataga formation have ribs with single flanges crossing them like the juvenile ribs of *P.* (*L.*) *poulcreekensis*, or the possible narrow ribbed subspecies of it illustrated on plate 38, figure 5.

Patinopecten (*Lituyapecten*) *yakatagensis* differs from *P.* (*L.*) *poulcreekensis* by having more ribs; about 28 to 31 as opposed to 22 well-defined ribs and 1 or 2 additional fine terminal radial riblets on *poulcreekensis*. The ribs of *poulcreekensis* are larger and broader. The lateral frills on the ribs of *yakatagensis* are separated from the time of their first appearance, whereas *poulcreekensis* has a long postjuvenile stage in which the frills are continuous across the ribs, and on some ribs they remain single. Furthermore, no specimens of *yakatagensis* have been observed in which the lateral frills divide again, whereas in *poulcreekensis* the frills on some of the ribs may divide secondarily to form four rows of frills.

The two species differ strikingly in the development of interstitial ribs; they are strong in *poulcreekensis* but very rare in *yakatagensis*. (See pl. 42, fig. 3.) There may be an incipient tendency towards the development of interstitial ribs on the right valve of *yakatagensis* (see pl. 37, fig. 2), but flanged interstitial ribs are always present on adults of *poulcreekensis*, and they are often as high as the primary ribs (see pl. 35, fig. 5).

In the tentative subspecies of *poulcreekensis* (pl. 38, fig. 5) weakly flanged interstitial ribs are present in some of the interspaces, but more interspaces are without them. In typical *poulcreekensis* only one or two interspaces at the terminal ends are apt to lack interstitial ribs.

The ears of *yakatagensis* are lower and longer than on *poulcreekensis;* the radial markings are finer; the suprabyssal extension of the anterior ear of the right valve is narrower and longer; and the anterior ear of the left valve tends to develop a submarginal roll or fold, a condition not apparent on any specimens of *poulcreekensis* seen. A fold is well developed in *coosensis* Shumard. (See Trumbull, 1958, pl. 117, fig. 4.)

Patinopecten (*Lituyapecten*) *yakatagensis* was probably the direct ancestor of *P.* (*L.*) *lituyaensis*, the species next described. The latter species occurs in beds believed to be equivalent to an upper part of the Yakataga formation, but so far no representatives of *Litu-*

yapecten are known from the highest part of the Yakataga formation. The beds containing *Lituyapecten* in the Lituya Bay area are believed to be late Miocene or early Pliocene in age. The subgenus is represented by still another species in beds of late Pliocene cage in California. Unless the pattern of distribution known at present is merely an accident of collecting, the subgenus seems to have migrated from the northern Gulf of Alaska region in the early Miocene to California in the late Pliocene where it became extinct.

An incomplete right valve from the lower part of the sandstone-siltstone unit in the Lituya Bay district (pl. 41, fig. 2) may be *P.* (*L.*) *yakatagensis* or, at least, intermediate between *P.* (*L.*) *yakatagensis* and *P.* (*L*). *lituyaensis*. It occurs lower in the section than typical *lituyaensis* although its position may be stratigraphically higher than the highest known occurrence of *yakatagensis* in the Yakataga formation. The ribs are narrower than on *lituyaensis*. There are 26 ribs; just under the minimum observed on *yakatagensis* in the Yakataga district and just over the maximum observed for *lituyaensis* from higher in the section in the Lituya Bay district.

Distribution.—Early to Middle Miocene, northern Gulf of Alaska region: Yakataga formation, Yakataga district, Alaska; possibly in the lower part of the sandstone-siltstone unit in the Lituya Bay district, Alaska.

Type locality.—Yakataga formation, about 350 feet above the base of the formation, Yakataga Reef, UC loc. 3859.

Other occurrences.—Yakataga formation, USGS locs. 6693, 6695, 15425, 15437(?), 17813, 17840, 17841, 17852, 17853, D256 (T); CAS locs. 29230, 29244, 29248, 29251, 29256, 29257, 29270, 29274, 29276, 29277, 29283, 29294; UC loc. 3858.

Doubtful identifications.—Sandstone-siltstone unit, Lituya Bay district, USGS D187 (T).

Patinopecten (Lituyapecten) cf. P. (L.) yakatagensis (Clark)

Plate 45, figure 3; plate 46, figure 5

The Miller collection from the upper 50 feet of the Poul Creek formation at Yakataga Reef (USGS 17733), Alaska, contains one specimen that is obviously different from other specimens from that interval, all of which appear to be referable to *poulcreekensis*. The unique specimen is more like *yakatagensis* although it is not typical. The significance of this specimen was not recognized in the field and it was not segregated, but an attempt to determine its stratigraphic position from the matrix adhering to it and Miller's very carefully described section suggests that it came from a bed stratigraphically higher than the bed containing abundant individuals of *poulcreekensis*.

This specimen has only about 24 ribs as opposed to 30 or 31 in the typical form. The ribs on its left valve have no flanges—only a weak sulcus on 1 or 2 ribs. The raised concentric microsculpture, which normally characterizes the juvenile stage, extends on this specimen all the way to the ventral margin. The specimen has a maximum height of about 90 mm; the transition from the juvenile to the adult sculpture on both *poulcreekensis* and *yakatagensis* is usually between 30 and 50 mm from the beak.

This form is the probable ancestor of typical *yakatagensis*, and since it occurs at so nearly the same stratigraphic position as *poulcreekensis*, and yet differs so much from it, the suggestion is strong that *poulcreekensis* is not the direct ancestor of *yakatagensis*. This problem is further discussed on page 232–233.

It is also possible that this form from the uppermost part of the Poul Creek formation may be ancestral to other late Tertiary pectinids besides *P.* (*L.*) *yakatagensis;* lineages which did not continue to live in the immediate area. One such possible descendent is *Patinopecten coosensis* (Shumard) from the Empire formation (Pliocene?) of Oregon which does not seem to be very closely related to the Miocene to Recent *P. propatulus*—*P. caurinus* stock, but which could very well have come from *P.* (*L.*) cf. *yakatagensis* from the Poul Creek.

Locality.—From the upper 50 feet of the Poul Creek formation at Yakataga Reef, Alaska, presumably from above the zone of *P.* (*L.*) *poulcreekensis*, USGS 17733.

Patinopecten (Lituyapecten) lituyaensis MacNeil, n. sp.

Plate 39, figures 1, 3; plate 40, figures 1–5; plate 41, figure 1; plate 42, figures 1, 2, 4; plate 43, figures 1–4

Shell large, asymmetrical; posterior extension greater than anterior extension, and greatest height posterior of median line; right valve more inflated than left valve; shell of medium thickness. Dorsal margins concave in region of ears, but become nearly straight distally; dorsal margins low; left valve may have a low steplike marginal slope, particularly along left side; left valve ears inflated and lie higher than adjacent disk; byssal fold may be greatly swollen. Dorsal margin of ears straight centrally but curves ventrally towards distal end; anterior ear of right valve curves strongly in large specimens. Ears of moderate size for a large shell; no denticles along margin; byssal sinus moderately deep; ears sculptured by scabrous or beaded radial riblets which tend to die out distally and which may be very weak or absent on some specimens; a weak dorsal fold and a corresponding terminal indentation on anterior ear of left valves. Both valves with about 23 or 24 broad radial ribs. Ribs of right valve higher centrally and low to nearly flush terminally; central ribs smooth and rounded on top; terminal ribs have weak lateral frills and concave tops; interspaces smooth or have frilled interstitial ribs in one or more of terminal interspaces. Left valve has frilled ribs, which may be single and narrow terminally but broad centrally with a raised row of strong but narrow beadlike frills on each side, or more rarely with a middle row of frills as well; interspaces wider than ribs in adults but narrower than ribs in juveniles, sometimes with beaded or frilled interstitial riblets in one or two interspaces. Juvenile sculpture of left valve consists of raised concentric growth lines which are slightly convex towards beak and which are not raised on bottoms of interspaces, but which are raised in median trough on ribs for some distance beyond first appearance of marginal frills. Microsculpture of adults consists of growth lines convex towards margin in interspaces and concave towards margins on ribs but not raised as in juveniles. Right valve microsculpture consists of faint radial markings but otherwise smooth.

Holotype, a right valve (USNM 563598), measures: diameter 210 mm, height 220 mm. The left valve paratype is numbered USNM 563599.

The holotype of this species is one of the largest Tertiary pectinids known—if a larger specimen has ever been reported—and fragments of other specimens indicate that an even larger size was attained; possibly as much as 250 mm. It may have the distinction also of being the first pectinid observed in the rocks of western North America, the "manteau royal" mentioned in the narrative of La Pérouse's expedition of 1786.

This species is descended probably directly from *P.* (*L.*) *yakatagensis*. It is larger and asymmetrical, whereas *yakatagensis* is nearly round. Most of the known specimens appear to be deformed by rock flowage in one way or another; some are shortened, some lengthened, and others are flattened. It has fewer and broader ribs than *yakatagensis*. The ears are larger and higher, and the byssal notch and the byssal fasciole are not as broad. The terminal ribs on the right valve of *yakatagensis* usually have a row of weak frills on the outer side, but the terminal ribs of *lituyaensis* usually have frills on both sides, and the ribs tend to be broader with a concave top. However, there is considerable variation in this respect; compare figure 1 of plate 40 with the corresponding area on figure 3.

The terminal ribs of the left valve of both species tend to be narrow and to have only a single set of beads or flanges; this feature differs from specimen to specimen, and opposite ends of the same specimen may be unlike. The left valve of *lituyaensis* sometimes has a strong third beaded riblet on some of the middle ribs (pl. 43, fig. 1), possibly a function of its wider ribs. Only one specimen of *yakatagensis* seen (pl. 42, fig. 3) has any indication of a third row of beads, and on it the third row is very weak. It is interesting to note that this specimen also has a fine beaded interstitial riblet, a variation which in *lityuaensis* accompanies the presence of the third beaded riblet on the ribs. *Patinopecten* (*L.*) *lituyaensis* has its flangelike beads in well-separated rows, the variation being from well to widely separated; in *yakatagensis* the rows range from narrowly to well separated, the maximum separation in *yakatagensis* being about the minimum separation in *lituyaensis*. The minimum separation in *yakatagensis* is about equal to the maximum separation in *poulcreekensis*, the latter species ranges to specimens having no division of the flanges.

The frilled interstitial ribs seen on several right valves of this species (pl. 39, fig. 3; pl. 40, figs. 2, 5) seem to be a common occurrence, and they resemble to a lesser degree the interstitial ribs of *P.* (*L.*) *poulcreekensis*. Similar ribs have not been observed in *yakatagensis*.

The microsculpture on juvenile left valves of *lituyaensis* (pl. 42, fig. 2) is similar to that of *yakatagensis* (pl. 37, figs. 3, 5). On both species the transition to the adult stage with side frills on the ribs is less abrupt than on *poulcreekensis* (pl. 36, fig. 6).

All three species are in contrast to a specimen, identified as *P.* (*L.*) cf. *yakategensis*, collected by Miller (pl. 45, fig. 3; pl. 46, fig. 5) from above the *P.* (*Y.*) *poulcreekensis* zone but still below the base of the Yakataga formation (included in USGS 17733).

This single and only known unfrilled specimen from the upper part of the Poul Creek formation poses a problem regarding the ancestry of both *yakatagensis* and *lituyaensis*. There seems to be little doubt that *lituyaensis* is descended directly from *yakatagensis*. However, in some respects the unfrilled Poul Creek form appears to be a more likely ancestor of typical *yakatagensis* than *poulcreekensis* does; *poulcreekensis*, although related, may belong to a different lineage that is more closely related to *P. dilleri*. The strongest resemblance between *yakatagensis* and *poulcreekensis* lies in the possession by both of divided flanges. The flanges of *poulcreekensis* are more exaggerated and have a greater range of variation than those of *yakatagensis*, its possible successor. On the other hand, the unfrilled Poul Creek form is what might be expected for the ancestor of *yakatagensis*. It has narrow ribs although they are fewer than in typical *yakatagensis*. The beaks and ears are similar, even to the fold along the dorsal margin of the anterior ear of the left valve, a condition also strongly developed in *P. coosensis*. (See Arnold, 1906, pl. 6, fig. 2.) The fact that the Poul Creek form does not have frills on its ribs may be outweighted by the fact that on some specimens of typical *yakatagensis* they are very weak and by the fact that the adult sculpture of the Poul Creek form is like the juvenile sculpture of *yakatagensis*.

It may be unsafe to draw conclusions on the few specimens known at present. It is possible, however, that *poulcreekensis* and the unfrilled form, here indentified as *P.* (*L.*) cf. *yakatagensis*, represent already divergent stocks of common ancestry and that *poulcreekensis* may be the ancestral stock of *dilleri*, whereas the unfrilled form may be the ancestral stock of the typical *yakatagensis* and *lituyaensis*, as well as of *coosensis*.

The next younger members of this group of pectinids are from the Pliocene of California; after *lituyaensis* none are known from Alaska.

Distribution.—Late Miocene(?) and (or) early Pliocene, Lituya Bay district, Alaska: Occurs in both the lower sandstone–siltstone unit and the upper mudstone unit.

Type locality.—Upper mudstone unit of unnamed upper Tertiary formation, about 300 to 340 feet above the base of the upper mudstone unit, southwest shore of Cenotaph Island, Lituya Bay, Alaska, USGS M270.

Other occurrences.—Lower sandstone(?)–siltstone unit, USGS D223 (T), D264 (T); upper mudstone unit, USGS D174 (T), M270.

Patinopecten (Lituyapecten) purisimaensis (Arnold)

Plate 44, figures 1, 3

Pecten (*Patinopecten*) *purisimaensis* Arnold, 1906, U.S. Geol. Survey Prof. Paper 47, p. 105, pl. 34, fig. 3, pl. 35, figs. 1, 1a.
Grant and Gale, 1931 [in part], San Diego Soc. Nat. History Mem., v. 1, p. 194, pl. 6, fig. 3.

The type of this species, deposited at Stanford University (SU 3), is a very poor specimen; and although a better right valve was figured by Grant and Gale, it has remained inadequately illustrated. The specimen figured here, although incomplete and partly riddled by borings, is by far the best specimen of the species I have seen and illustrates most of its characters very well.

The typical form of the species has rather narrow ribs on its right valve, and most of the ribs have short marginal denticles or flares recalling those on the terminal ribs of *P.* (*L.*) *lituyaensis*. (See pl. 41, fig. 1.) The left valve has narrow ribs with wide, round-bottomed interspaces. Two or three of the central ribs are slightly wider with a weak concavity along the crest, but most of the ribs are narrowly rounded on top and bear a single row of denticles or narrow flanges along their crest. They are broken or worn on most specimens observed, and even on the fairly well preserved specimen figured here, only their base is preserved.

Patinopecten turneri Arnold from the Pliocene of the Tomales Bay region, California, was regarded by Grant and Gale (1931, p. 194) as a synonym of *purisimaensis*. If Grant and Gale were influenced by an error in Arnold's statements about his figured specimens they did not say so. Arnold figured three specimens, two of them as right valves and one as a left valve; however, all three of Arnold's specimens are left valves. This gave him an erroneous concept of his supposed new species and made it appear to be very different from *purisimaensis*. Actually *purisimaensis* and *turneri* are closely related, but some good specimens of *turneri* collected by Dr. Joseph H. Peck of the University of California show a well-defined sulcus on the right valve ribs that is not found in *purisimaensis*. These species should probably be kept separate.

Patinopecten (*L.*) *purisimaensis* is related to *P.* (*L.*) *dilleri* (Dall), a species common in the Pliocene of southern California but decribed from the Pliocene of Humboldt County, northern California. *P.* (*L.*) *dilleri* usually has coarse flanges on both valves, those of the right valve being either single and crossing the ribs (Arnold, 1906, pl. 5, fig. 2), or divided and along the margins of the ribs (Woodring and Bramlette, 1950, pl. 11, fig. 1). The left valve has strong single flanges (Woodring and Bramlette, 1950, pl. 11, fig. 9). It is doubtful if *dilleri* should be regarded as a variety of *coosensis* as was done by Grant and Gale (1931, p. 193). In view of the Alaskan forms now known, it seems more likely that *dilleri* and *coosensis* stem from different early Miocene forms; *dilleri* from *poulcreekensis*, and *coosensis* from an early variant of *yakatagensis*.

In spite of its apparent close relation to *dilleri*, *purisimaensis* appears to be more closely related to *falorensis*, a species here described from the Falor formation (Manning and Ogle, 1950) of northern Humboldt County, Calif., a formation equivalent to a part of the Wildcat series of Lawson (1894). In fact, it is difficult to say from the known specimens whether two species are represented in the Purisima formation, *purisimaensis* and *falorensis*, or whether all the specimens in question should be regarded as belonging to one greatly variable species. For the time being they are treated as two species although it may later be found preferable to treat *falorensis* as a subspecies of *purisimaensis*.

Distribution.—Pliocene, central California: Purisima formation, San Mateo County, Calif.

Type locality.—North of the mouth of Pescadero Creek, San Mateo County, Calif., SU 3.

Other occurrences.—UC 4417, SU 4922.

Patinopecten (Lituyapecten) falorensis MacNeil, n. sp.

Plate 38, figures 1, 3; plate 44, figures 2, 4; plate 45, figures 2, 4; plate 46, figures 1–4

Pecten oregonensis Howe var. Manning and Ogle, 1950, Calif. Div. Mines Bull. 148, p. 23–24, pls. 6, 7.

Shell moderately large; suborbicular to weakly extended posteriorly; valves moderately inflated; right valve slightly more inflated than left valve; shell moderately thin. Posterior dorsal margin moderately concave, and anterior margin nearly straight; left valve with low but sharp steplike submarginal slopes, and right valve slopes less sharp because of inflation of ears. Dorsal margin of ears straight. Ears sculptured by radial riblets with moderately strong beads, about seven riblets on posterior ear of left valve; posterior ears longer and with stronger radial riblets than anterior ears; no denticles along byssal sinus; dorsal margin of left ear of left valve with a weak swelling or fold. Ribs 21 to 23. Right valve often having a split rib, one segment having no counterpart on left valve; right valve ribs broad with undercut sides, interspaces narrow and deep; bottoms flattened; central ribs flattened or rounded on top; terminal ribs with a median sulcus which at the margin may be nearly as deep and wide as the primary interspaces. Left valve ribs moderately broad with a row of short flanges or denticles along each side; central area depressed and troughlike; three terminal ribs on each side narrow and with a single row of short flanges on their crest; interspaces round-bottomed and narrower than the ribs on some specimens, wider on others; no interstitial riblets on any specimens observed. Juvenile microsculpture unknown.

Holotype, both valves together (right valve, UC 34172, left valve UC 34171) measures; diameter 107 mm, height 99 mm. Figured specimen UC 15977 has a height of 130 mm.

The specimen figured by Manning and Ogle, refigured here and made the holotype of the species, is the only specimen of a *yakatagensis*-like *Lituyapecten* figured previously other than the type of *yakatagensis* itself. Its relationship to *yakatagensis* was not recognized and instead, it was identified tentatively as a variety of *P. oregonensis* Howe, a species described from the Empire formation of western Oregon. Possibly the association of this species with *oregonensis* came about because of the incorrect locality data given by Howe for a specimen he figured. This specimen (Howe 1922, pl. 11, fig. 2) was stated by Howe to be from the Wildcat series of Humboldt County, Calif.; but according to its number (N. P. 82 of the Arnold catalog; not 28 as stated by Howe), it comes from north of the mouth of the Raft River, Taholah, Grays Harbor County, Wash., a locality of indefinite formational assignment. There might have been some question, had the specimen figured by Howe actually come from the Wildcat series, as to whether it was *oregonensis* or *falorensis*, because it is very difficult to identify right valves, even on specimens whose left valves are very dissimilar. However, its correct locality together with the fact that it compares favorably with other right valves of *oregonensis* makes it safe to assume that it belongs to that species.

There are two specimens in the Manning and Ogle collection besides the holotype. They are smaller than the type, but they appear to have narrower ribs than the corresponding stage on the type. In this respect they approach some of the typical specimens of *P. purisimaensis*. The left valves of these two specimens have narrow but definitely flat-topped ribs with denticulate margins like the specimen from the Purisima formation illustrated on plate 45, figure 2, here referred to *P.* (*L.*) *falorensis*. Typical *P.* (*L.*) *purisimaensis*, on the other hand, has narrow rounded ribs over most of its disk with two or three of the central ribs slightly wider and having a weak concavity along the crest. (See pl. 44, figs. 1, 3.) The Purisima formation also contains a form that has wide ribs on the right valve and broad, flat-topped ribs with marginal denticles on the left valve (pl. 44, figs 2, 4), and that compares favorably with the type of *falorensis*.

Although it is difficult to say how many species are involved here and, if they are distinct, just what the varietal range of each species is, it is fairly certain that *purisimaensis* and *falorensis* are very closely related. *P.* (*L.*) *yakatagensis* is a highly variable species if all the specimens here referred to it are really conspecific. The same range of variation has not been noted in *lituyaensis*, but possibly all variants of that species have not been found. If approximately the same range of variation could be demonstrated for *lituyaensis*, a strong case for considering *falorensis* as a variety or, at most, a subspecies of *purisimaensis* could be made. To state the problem another way, it is not known whether *purisimaensis* and *falorensis* represent divergent stocks of common but not too distant ancestry or whether the three species, *yakatagensis*, *lituyaensis*, and *purisimaensis* (including *falorensis*) are linear elements of one very variable stock, no parts of it having been clearly set off by geographical isolation. If the latter were so, all the variants existing at any particular instant of time belonged to one species, whereas the mean of variation shifted sufficiently through time to make at least three distinct species recognizable.

The Stanford University collection contains another specimen from the Purisima formation (pl. 45, fig. 4;

pl. 46, fig. 1) that has wide ribs on the left valve like those of typical *falorensis*. However, the right valve has high, comparatively narrow ribs that approach those of typical *purisimaensis*. Furthermore, some of the interspaces on the right valve have strong interstitial ribs, almost as strong as those of *P.* (*L.*) *poulcreekensis*. On the basis of its left valve, and because some individuals of *falorensis* have narrower ribs than the type, I am identifying this specimen as *falorensis*. A similar specimen, except that it lacks interstitial ribs, is in the University of California collection (UC 32659).

Distribution.—Pliocene, northern and central California: Falor formation of Manning and Ogle, 1950, northern Humboldt County; Rio Dell formation of Ogle, 1953 (Wildcat series of Lawson, 1894), Humboldt County; Purisima formation, San Mateo County, Calif.

Type locality.—Falor formation, near bridge crossing Boulder Creek, adjacent to the Wiggins Rach, about 10 miles southeast of Blue Lake, Humboldt County, Calif., UC A4233.

Other occurrences. —Falor formation, SU 4837; Rio Dell formation, SU 4932, SU 4937; Purisima formation, UC 1780 (32659), UC 1788, UC A4343, SU 1095, SU 29788.

Patinopecten (Lituyapecten) cf. P. (L.) dilleri (Dall)

Plate 41, figures 4, 5; plate 45, figure 1

The following is a partial synonymy for typical *P.* (*L.*) *dilleri*:

Pecten (*Lyropecten*) *dilleri* Dall, 1901, Nautilus, v. 16, no. 10, p. 117.

Pecten (*Patinopecten*) *dilleri*. Arnold, 1906, U.S. Geol. Survey Prof. Paper 47, p. 62, pl. 5, fig. 2.

Jordan and Hertlein, 1926, California Acad. Sci. Proc., v. 15, no. 14, p. 431, pl. 30, fig. 1.

Pecten (*Patinopecten*) *coosensis* Shumard variety *dilleri* Dall. Grant and Gale, 1931, San Diego Soc. Nat. History, Mem. 1, p. 193.

Patinopecten dilleri. Woodring *in* Woodring and Bramlette, 1951, U.S. Geol. Survey Prof. Paper 222, p. 84, pl. 11, figs. 1, 9 [imprint date 1950].

Fragments of a large *Patinopecten* which may represent a new species were collected from a horizon high in the Lituya Bay section. One large fragment of a left valve and two small fragments of a right valve are represented. The left valve (pl. 45, fig. 1) has moderately broad rounded ribs with irregular flanges crossing them and broader, round-bottomed interspaces; at least one of the interspaces has a weak interstitial riblet bearing fine flanges. The right valve (pl. 41, figs. 4, 5) has broad, slightly undercut ribs and narrower deep interspaces. The fragments appear to be from the central part of the disk. No denticles or flanges are present on the right valve fragments although terminal ribs might have them.

The right- and left-valve fragments figured here are believed to be the same species, if not the same individual, but there is no assurance that this is so. If they are, the Alaskan form has much broader ribs on its right valve than does typical *dilleri* from California; the right valve also lacks the spiny lamellae commonly present on the southern form. (See Woodring, 1950, pl. 11, fig. 1.)

A nearly perfect specimen of *dilleri* with both valves together was collected by E. H. Quale in the city of San Diego. It is in the collection of the University of California at Los Angeles, (UCLA 8072, plesiotype No. 309) and is to be figured in a forthcoming paper on the fauna of the San Diego formation by L. G. Hertlein. The left valve of this specimen has the typical single-flanged ribs of the species, but the right valve has nearly smooth, moderately narrow ribs. Probably this specimen and the specimen figured by Woodring (1950, pl. 11, fig. 1) with strong lateral lamellae on the right valve ribs can be taken as nearly opposite extremes in right-valve ornamentation.

The left valve from Lituya Bay appears to be more like a specimen of *dilleri*, figured by Jordan and Hertlein (1926), from Pliocene beds near Elephant Mesa in the Scammon Lagoon quadrangle, Lower California, than any figured from farther north. The Lower California specimen has elongate flanges which are single on most ribs; on some ribs the flanges break up into two series with the opposite elements alternating, a condition found on some of the ribs of *P.* (*L.*) *poulcreekensis*. (See pl. 35, fig. 6, and pl. 36, fig. 4.) Usually, as on the specimen figured by Woodring (1950, pl. 11, fig. 9), the flanges on the left-valve ribs are shorter and more regular.

Of several good specimens, including the holotype, from the Wildcat series of Lawson (1894), all but one show only, or consists of only, the right valve. One lot from the Tomkins Hill Gas Field, Humboldt County (CAS 34391), consists of a rubber cast of a large, nearly perfect right valve (presumably made in the field) and shells of two incomplete left valves. The left valves appear to be very similar to the specimen figured from Elephant Mesa, Lower California.

There seems to be little doubt that *dilleri* is a *Lituyapecten*. It is a highly variable species if all the specimens that have been referred to it are really conspecific. Among pectens of its own age, it appears to be most closely related to *P.* (*L.*) *purisimaensis* as numerous writers have claimed. However, it has characters which link it unmistakably with both *P.* (*L.*) *poulcreekensis* and *poulcreekensis* var. (pl. 38, fig. 5), both, early Miocene forms. Its relation to *purisimaensis* may be, therefore, one of parallellism rather than of direct intergradation, *purisimaensis* merely representing the varietal extreme of the *purisimaensis-falorensis* stock that perpetuated more of the characters that both it and the *dilleri* stock inherited from a common early Miocene ancestor.

Woodring (1950, pl. 9, figs. 6–8) figured three left valves from the Sisquoc formation of the Santa Maria district, California, as "*Patinopecten dilleri* variety." This form has well-developed interstitial riblets, concentric frills which completely bridge the interspaces between the ribs (crossing the interstitial ribs in so doing), and a well-developed imbricating microsculpture resembling the surface of metal lath. I have not seen any of these characters on other members of the *dilleri* group. In spite of its excellent preservation, this is a very puzzling shell. It will be interesting to see what its right valve looks like, if and when one is found. Dr. Leo G. Hertlein, of the California Academy of Sciences, who has had a long and special interest in west-coast pectinids, tells me that he does not believe it is a *Patinopecten* and that he knows of no other west-coast species like it. It could be the left valve of the species described by Arnold (1906, p. 117, pl. 45, figs. 3, 4) as *Pecten* (*Chlamys*) *lawsoni*. Arnold figured two fragments, one as a left valve and one as a right valve; both of them may be right valves. Grant and Gale (1931, p. 166) and Woodring (1950, p. 83) tentatively put *lawsoni* in the synonymy of *Chlamys hastatus* (Sowerby). Unfortunately, the types of *lawsoni* were lost in the San Francisco fire of 1906.

Distribution.—The Alaskan specimens identified as *Patinopecten* (*Lituyapecten*) cf. *P.* (*L.*) *dilleri* are from the upper mudstone unit of an unnamed Tertiary formation, Lituya district, Alaska, USGS 7931.

The following is the known distribution for typical *P.* (*L.*) *dilleri:* Lower California and California. Pliocene beds near Elephant Mesa, Scammon Lagoon quadrangle, Lower California, Mexico; San Diego Calif.; Puente Hills and Newport Beach Los Angeles basin, California; Hills north of Simi Valley, Ventura County, Calif.; Foxen mudstone, and Cebada fine-grained member of the Careaga sandstone, Santa Maria district, California; Rio Dell formation of Ogle, 1953 (Wildcat series of Lawson, 1894), Eel River basin, Humboldt County, Calif.

Type locality.—Bluffs opposite Rio Dell, Eel River, Humboldt County, Calif., (USNM 164846) USGS locality 3363.

Other occurrences.—Lower California: SU 4936 (CAS 2095); San Diego, UCLA 8072; Puente Hills, Pomona College collection; Newport Beach (fide J. G. Vedder); Santa Susana, SU 4828; Simi Valley, UCLA collection; Santa Maria district, USNM 560053, USGS 14649, SU 4942; Eel River, SU 4821, CAS 117; Tomkins Hill Gas Field, CAS 34391.

Patinopecten (Patinopecten) caurinus (Gould)

Pecten caurinus Gould, 1850, Boston Soc. Nat. History Proc., v. 3, p. 345.

Pecten (*Patinopecten*) *caurinus*. Dall, 1898, Wagner Free Inst. Sci. Trans., v. 3, p. 710.

Pecten (*Chlamys*) *caurinus*. Oldroyd, 1924, Stanford Univ. Pub. Geol., v. 1, p. 57, pl. 6, fig. 1, pl. 4, fig. 1.

Pecten (*Patinopecten*) *caurinus*. Grant and Gale, 1931 [in part], San Diego Soc. Nat. History Mem. 1, p. 194. pl. 6, fig. 4. (See for extended bibliography.)

Grant and Gale discuss this species at length and cite a long bibliography. Not all of their synonymy is correct, however; certainly *propatulus* Conrad and *oregonensis* Howe, although related, do not belong to this species.

This species, the type of *Patinopecten*, is here regarded as being subgenerically distinct from the other species treated in this paper. No attempt is made to list all the fossil occurrences. It is included for the purpose of recording its occurrence at two localities in the upper part of the Yakataga formation, one in the Yakataga district and one in the Malaspina district. It occurs well above the highest occurrence of *P.* (*L.*) *yakatagensis*. If the present inferred correlation is correct, its earliest occurrence in the Yakataga district falls within the age range of *P.* (*L.*) *lituyaensis* in the Lituya district. The specimens are not well preserved and are not figured.

Localities.—Yakataga formation, CAS 29280, USGS D263 (T), D336 (T).

Vertipecten sp. indet.

Another pectinid, possibly a *Vertipecten*, which so far is known only from fragments and internal molds, occurs in the Yakataga formation at about the same stratigraphic position as *P.* (*L.*) *yakatagensis*. This form has a long anterior ear on its right valve, narrower and more numerous ribs, and moderately high dorsal slopes. It may be related to *V. porterensis* (Weaver). It is still too poorly known to be described.

Patinopecten (*Lituyapecten*) *poulcreekensis* has a superficial resemblance to some species of *Vertipecten*, and it occurs in beds of the same approximate age. Both have rather smooth ribs on the right valve and scabrous ribs on the left valve. However, although the ribs of the left valve of *Vertipecten* have large frills, the frills do not show any tendency to become divided into two well-defined rows, the common condition in adults of *Lituyapecten*. The right valve of *Vertipecten* has a rather steep umbonal slope. The left valve has a strong imbricating microsculpture, and there is a tendency for the ribs to be unequal. In some species [*V. nevadanus* (Conrad)], there is a tendency for every fourth rib to be stronger, whereas in others [*V. fucanus* (Dall)] one central rib may be stronger than the others. Left valves of *Vertipecten* are more inflated than right valves.

Occurrence.—The stratigraphic occurrence of this supposed *Vertipecten* is indicated by an asterisk in figure 46; CAS 29246, 29253, 29287, 29290. Another float specimen, presumably from the lower part of the Yakataga formation, is numbered USGS 17797.

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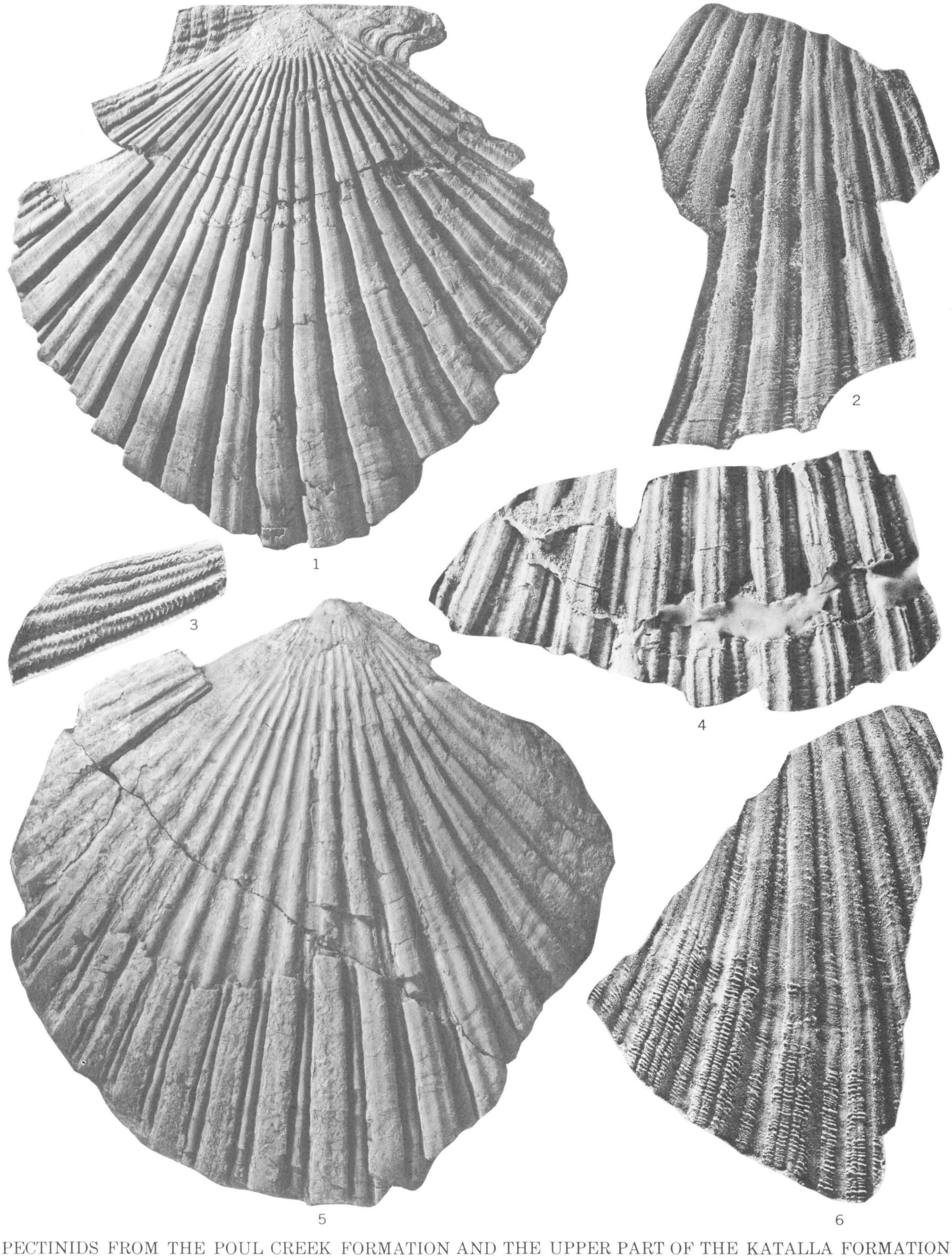
PLATES 35–46

PLATE 35

[Figs. 1–5 slightly reduced; 6, × 1. All specimens from Poul Creek formation, USGS M271, unless otherwise indicated]

FIGURE 1–6. *Patinopecten* (*Lituyapecten*) *poulcreekensis* MacNeil, n. sp. (p. 228).

1. Holotype, a right valve, USNM 563572; height 113 mm; diameter 113 mm.
2. Fragment of right valve, USNM 563574, rubber cast, showing frilled interstitial ribs.
3. Left dorsal margin of right value, USNM 563575, rubber cast, showing frilled terminal ribs.
4. Fragment of right valve, USNM 563576, rubber cast, showing a variation in the top surface of the ribs.
5. Incomplete and decorticated right valve, USNM 563577, showing strong development of interstitial ribs; diameter about 145 mm. Poul Creek formation, USGS 17733.
6. Fragment of left valve, USNM 563578, rubber cast, showing division of frills into 4 or 5 narrow rows; ribs decorticated on younger stages. Katalla formation, upper part, USGS 15852.



PECTINIDS FROM THE POUL CREEK FORMATION AND THE UPPER PART OF THE KATALLA FORMATION

579101 O - 61 - 3

PLATE 36

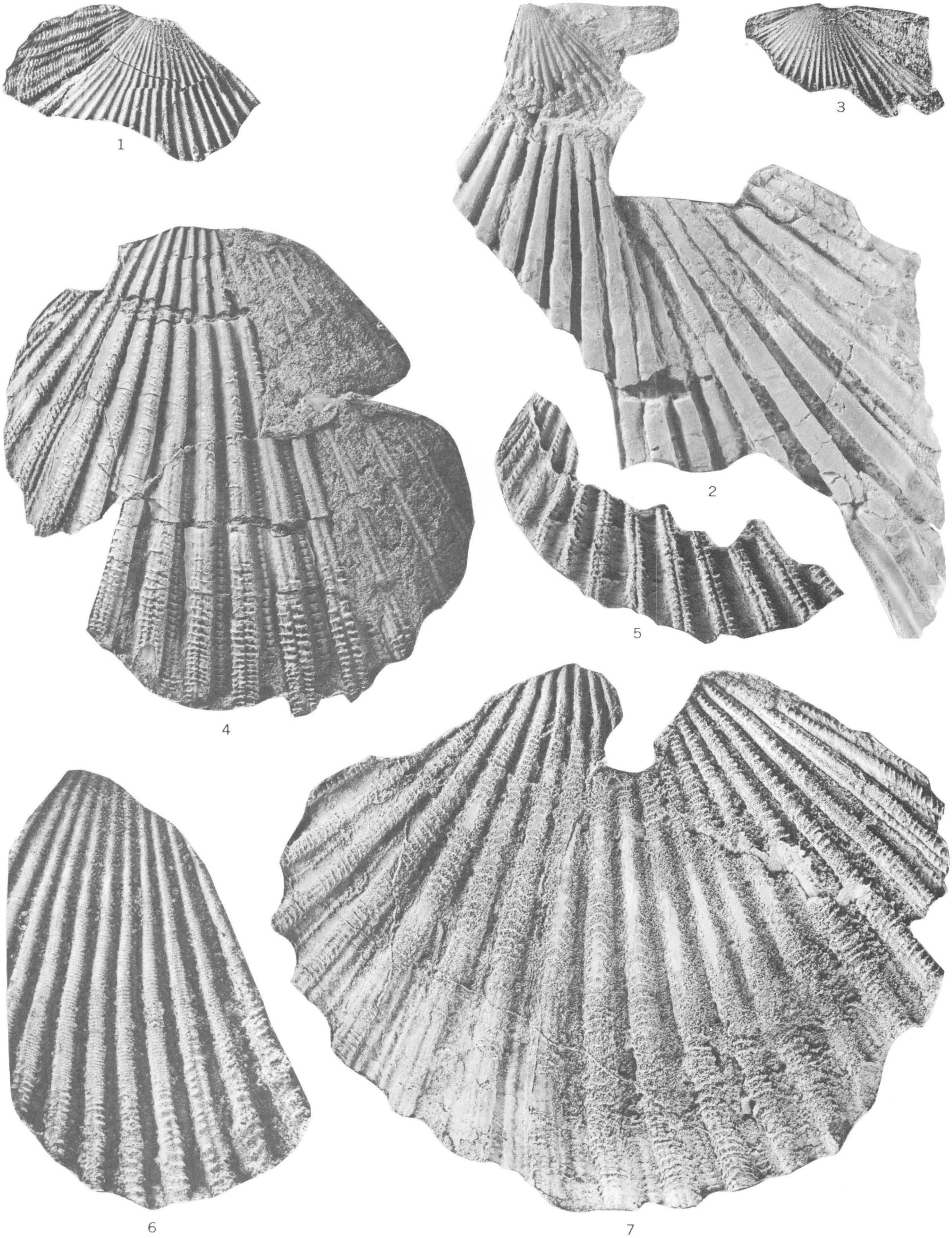
[All figures slightly reduced and from Poul Creek formation, USGS M271, unless otherwise indicated]

FIGURES 1, 3, 4, 6, 7. *Patinopecten* (*Lituyapecten*) *poulcreekensis* MacNeil, n. sp. (p. 228).

1. Left ear of left valve, USNM 563579, rubber cast.
3. Right ear of left valve, USNM 563580, rubber cast.
4. Paratype, incomplete left valve, USNM 563573, rubber cast; height of fragment 104 mm.
6. Fragment of left valve, $\times 2$, USNM 563581, rubber cast, showing juvenile sculpture.
7. Incomplete left valve, USNM 563582, rubber cast, showing variations in sculpture.

2. *Patinopecten* (*Lituyapecten*) cf. *P.* (*L.*) *poulcreekensis* MacNeil (p. 228).
Shell material adhering to a large specimen, USNM 563585; part not shown an internal mold; height of entire specimen 160 mm, nearly complete. Katalla formation, upper part, USGS 15843.

5. *Patinopecten* (*Lituyapecten*) *poulcreekensis* MacNeil, subsp.? (p. 229).
Fragment of left valve, $\times 1$, USNM 563584. Near base of Yakataga formation or top of Poul Creek formation, USGS D341 (T)



PECTINIDS FROM THE POUL CREEK FORMATION, THE UPPER PART OF THE KATALLA FORMATION, AND THE UPPERMOST POUL CREEK OR LOWERMOST YAKATAGA FORMATION

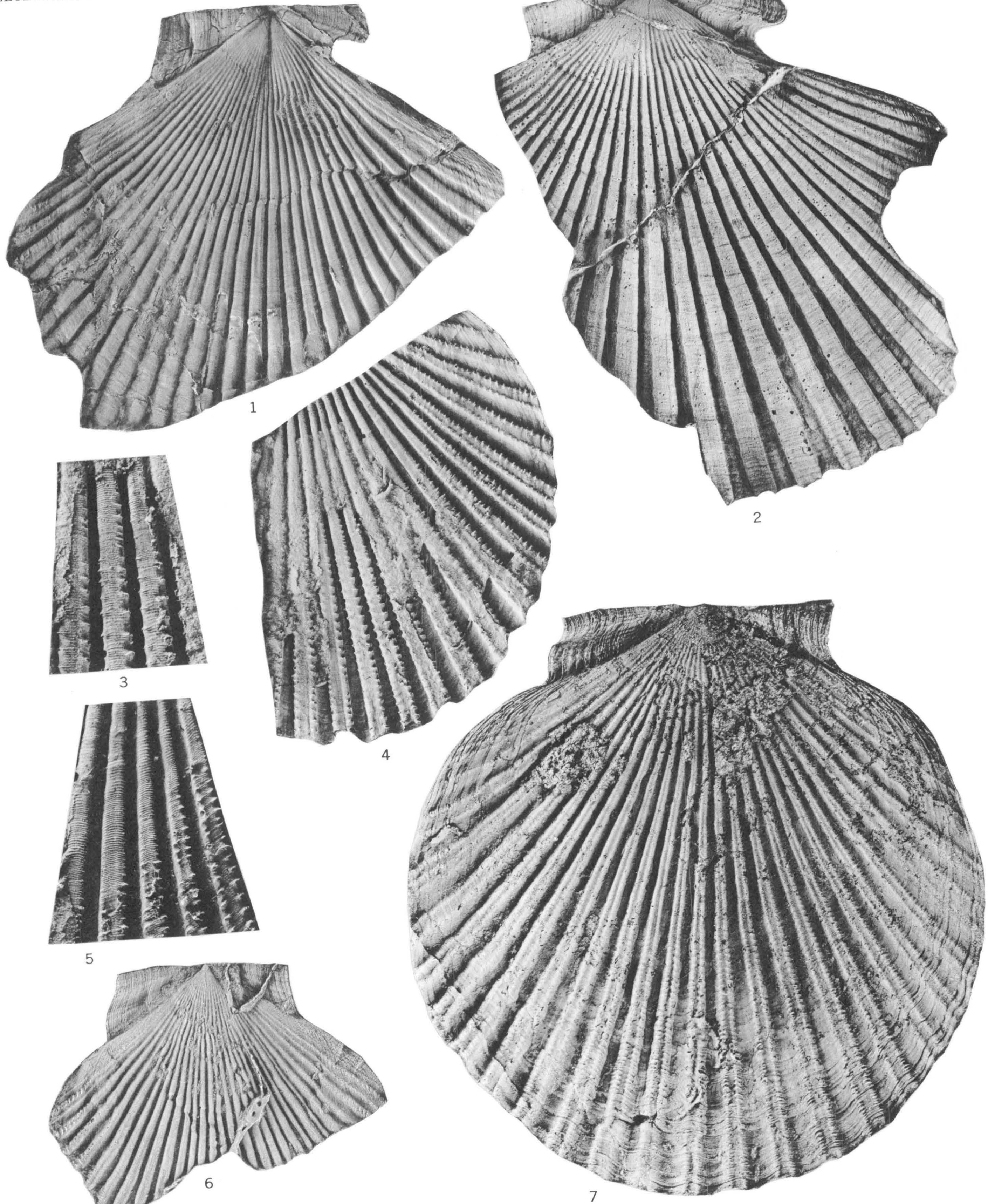
PLATE 37

FIGURES 1–7. *Patinopecten* (*Lituyapecten*) *yakatagensis* (Clark) (p. 229).

1. Right valve, ×1, USNM 563586, rubber cast, incomplete and crushed, showing marginal denticles on the terminal ribs. Yakataga formation, USGS 15425.
2. Incomplete right valve, slightly reduced, USNM 563587, rubber cast; note the weakly developed interstitial ribs; height 104 mm. Yakataga formation, USGS 15425.

3, 4, 5. Fragment of left valve, USNM 563588, rubber cast, showing juvenile sculpture and adult ribs with strong well-divided flanges. 3 and 5 are ×2 enlargements of parts of 4 (×1). Yakataga formation, USGS 6693.

6. Incomplete left valve, ×1, USNM 563589, rubber cast, a juvenile, showing early appearance of single frills on terminal ribs. Yakataga formation, USGS 15425.
7. Mature left valve, slightly reduced, USNM 563590, rubber cast, showing weaker and less divided flanges than figure 4; note the strong marginal fold of left ear; height 123 mm; diameter 123 mm. Yakataga formation, USGS 17813.



PECTINIDS FROM THE YAKATAGA FORMATION

PLATE 38

FIGURES 1, 3. *Patinopecten* (*Lituyapecten*) *falorensis* MacNeil, n. sp. (p. 234).

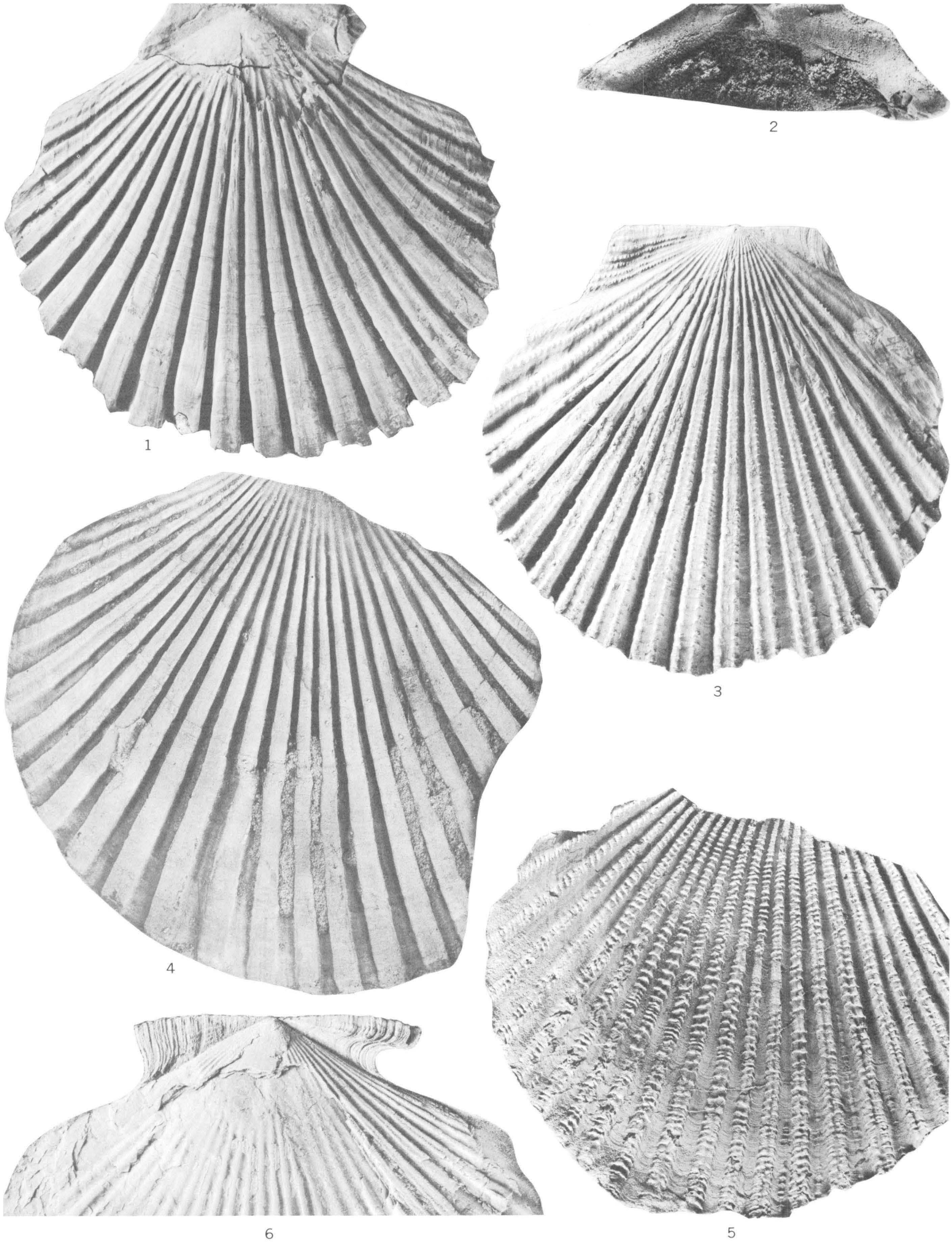
1. Holotype, right valve, slightly reduced, UC 34172; height 110 mm; diameter 115 mm. Falor formation of Manning and Ogle (1950), UC A–4233.
3. Holotype, left valve, slightly reduced, UC 34171. Falor formation of Manning and Ogle (1950), UC A–4233.

2. *Patinopecten* (*Lituyapecten*) *poulcreekensis* MacNeil, n. sp. (p. 228).
Incomplete hinge of a left valve, ×1, USNM 563583, rubber cast. Poul Creek formation, USGS M271.

4, 6. *Patinopecten* (*Lituyapecten*) *yakatagensis* (Clark) (p. 229).

4. Incomplete right valve, slightly reduced, USNM 563591, rubber cast. Yakataga formation, USGS 6695.
6. Hinge part of a decorticated right valve, slightly reduced; same specimen as plate 37, figure 7; destroyed in acid to obtain mold of left valve. Yakataga formation, USGS 17813.

5. *Patinopecten* (*Lituyapecten*) *poulcreekensis* MacNeil, subsp.? (p. 229).
Incomplete left valve, X 1, rubber cast. Float, upper part of Poul Creek formation or lower part of Yakataga formation, CAS 29285.



PECTINIDS FROM THE POUL CREEK FORMATION, THE YAKATAGA FORMATION, AND THE FALOR FORMATION OF MANNING AND OGLE, 1950 (CALIFORNIA)

579101 O - 61 - 4

PLATE 39

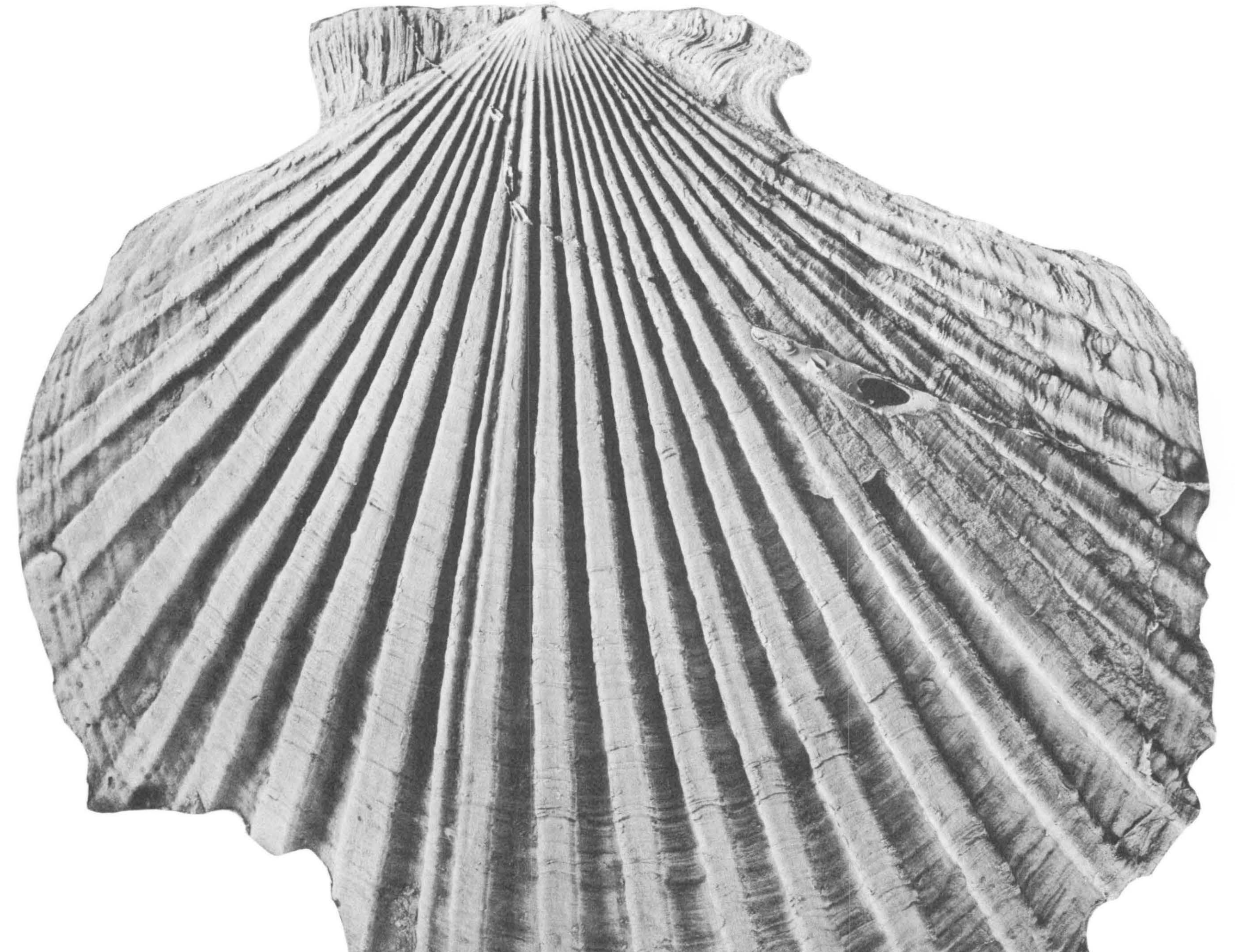
FIGURES 1, 3. *Patinopecten* (*Lituyapecten*) *lituyaensis* MacNeil, n. sp. (p. 231).

Both from unnamed upper Tertiary formation, upper mudstone unit, USGS M270.

1. Holotype, a right valve, about $\times 5/6$, USNM 563598, rubber cast; height 220 mm; diameter 210 mm.
3. Ears and left dorsal margin of a right valve, slightly reduced, USNM 563600, rubber cast, showing a variation in sculpture of ears and ornamentation of marginal ribs.

2. *Patinopecten* (*Lituyapecten*) *yakatagensis* (Clark) (p. 229).

Incomplete right valve, $\times 1$, USNM 563592, rubber cast. Yakataga formation, USGS 17852.



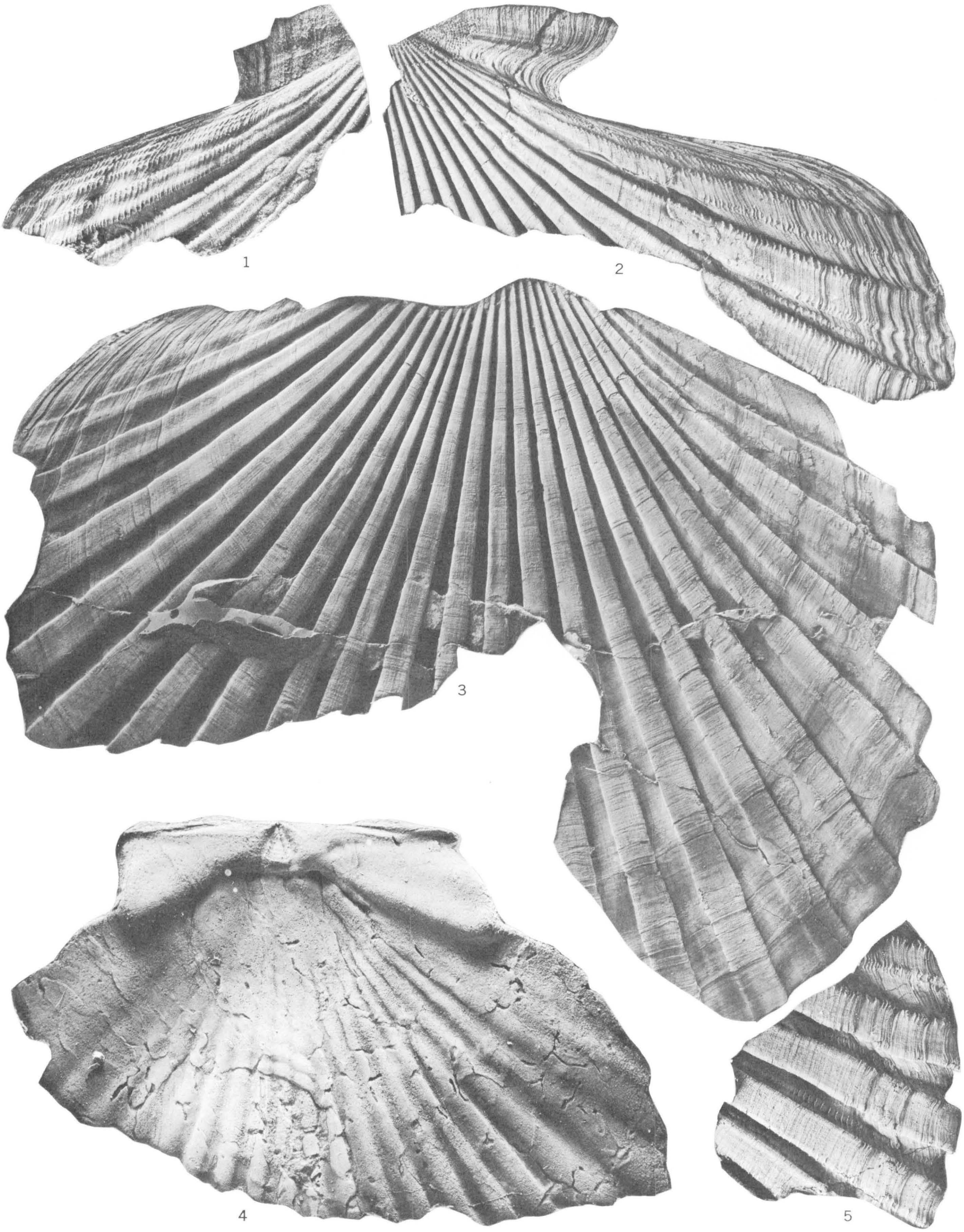
PECTINIDS FROM THE YAKATAGA FORMATION AND THE UPPER MUDSTONE UNIT OF THE UNNAMED UPPER TERTIARY FORMATION IN THE LITUYA DISTRICT

PLATE 40

[All from unnamed upper Tertiary formation, upper mudstone unit, USGS M270]

FIGURES 1-5. *Patinopecten* (*Lituyapecten*) *lituyaensis* MacNeil, n. sp. (p. 231).

1. Left dorsal margin of right valve, ×1, USNM 563601, rubber cast, showing marginal frills on terminal ribs.
2. Right dorsal part of right valve, ×1, USNM 563602, rubber cast, showing marginal frills on terminal ribs.
3. Incomplete right valve, slightly reduced, USNM 563603, rubber cast, a specimen without marginal frills on terminal ribs.
4. Hinge of left valve, slightly reduced, USNM 563604, rubber cast.
5. Fragment of right valve, slightly reduced, USNM 563605, rubber cast, showing well-developed frilled interstitial riblets.



PECTINIDS FROM THE UPPER MUDSTONE UNIT OF THE UNNAMED UPPER TERTIARY FORMATION IN THE LITUYA DISTRICT

PLATE 41

FIGURE 1. *Patinopecten* (*Lituyapecten*) *lituyaensis* MacNeil, n. sp. (p. 231).

Incomplete right valve, slightly reduced, USNM 563606, rubber cast, showing ears and details of sculpture; note greater asymmetry in advanced growth stages. Unnamed upper Tertiary formation, upper mudstone unit, USGS M270.

2. *Patinopecten* (*Lituyapecten*) *yakatagensis* (?) (Clark) (p. 231).

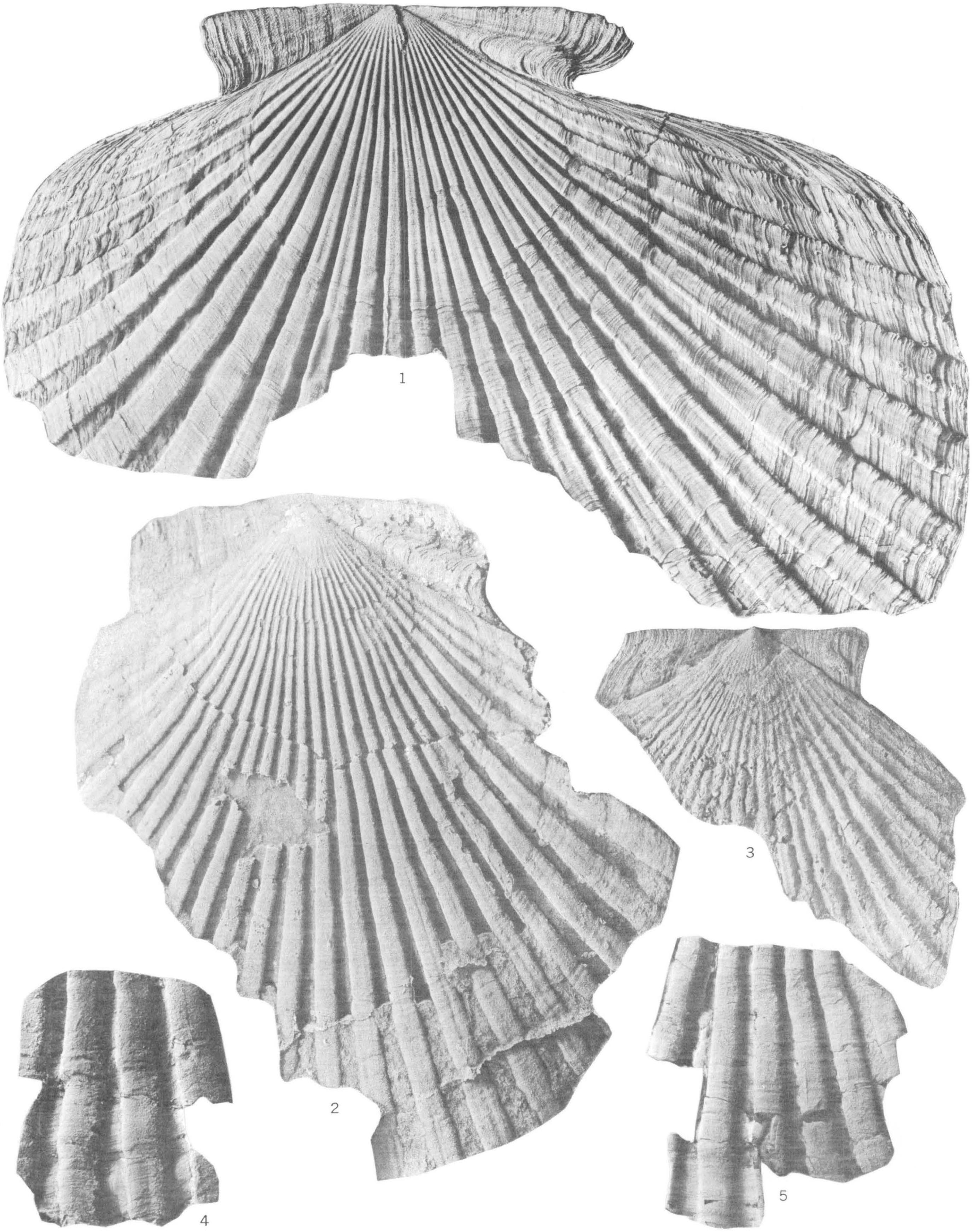
Incomplete right valve, ×1, USNM 563595, rubber cast. Unnamed upper Tertiary formation, lower sandstone-siltstone unit, USGS D187 (T).

3. *Patinopecten* (*Lituyapecten*) *yakatagensis* (Clark) (p. 229).

Incomplete left valve, ×1, USNM 563593, rubber cast. Yakataga formation, USGS 15425.

4, 5. *Patinopecten* (*Lituyapecten*) cf. *P.* (*L.*) *dilleri* (Dall) (p. 235).

Right-valve fragments, ×1, USNM 563612, 563613, in contact with and possibly same individual as left valve on plate 45, figure 1; ribs are undercut and without marginal frills or lamellae. Unnamed upper Tertiary unit, upper mudstone unit, USGS 7931.



PECTINIDS FROM THE YAKATAGA FORMATION AND THE LOWER SANDSTONE-SILTSTONE AND UPPER MUDSTONE UNITS OF THE UNNAMED UPPER TERTIARY FORMATION IN THE LITUYA DISTRICT

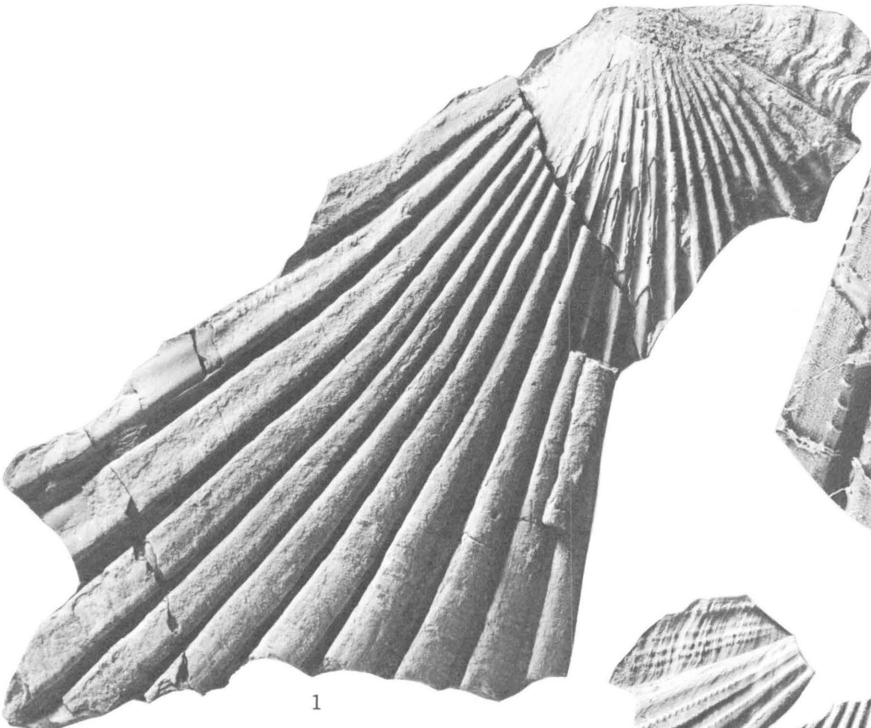
PLATE 42

FIGURES 1, 2, 4. *Patinopecten* (*Lituyapecten*) *lituyaensis* MacNeil, n. sp. (p. 231).

1. Incomplete right valve, × 1, USNM 563607; stratigraphically the oldest known occurrence of the species. Unnamed upper Tertiary formation, lower sandstone-siltstone unit, USGS D264 (T).
2. A × 2 enlargement of a part of the paratype, figure 4.
4. Paratype, a left valve, slightly reduced, USNM 563599, rubber cast; the mold from which this cast was made was formed naturally by humic acids; specimen probably is laterally compressed. Unnamed upper Tertiary formation, upper mudstone unit, USGS M270.

3. *Patinopecten* (*Lituyapecten*) *yakatagensis* (Clark) (p. 230).

Fragment of a left valve, × 1, USNM 563594, rubber cast, with barnacles adhering, showing an interstitial riblet and a weak middle row of denticles on one rib. Yakataga formation, USGS 17853.



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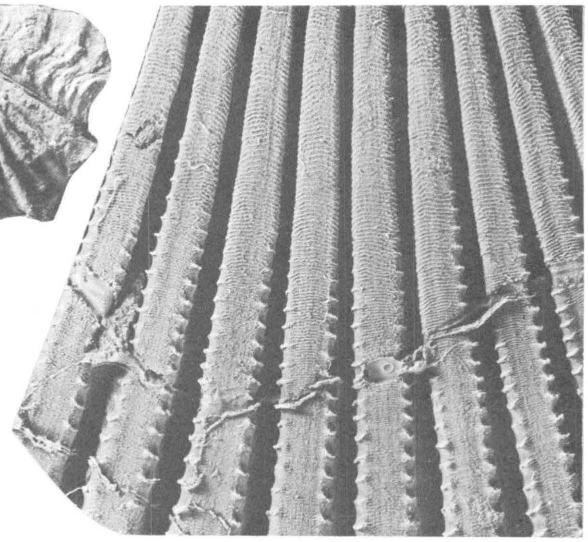

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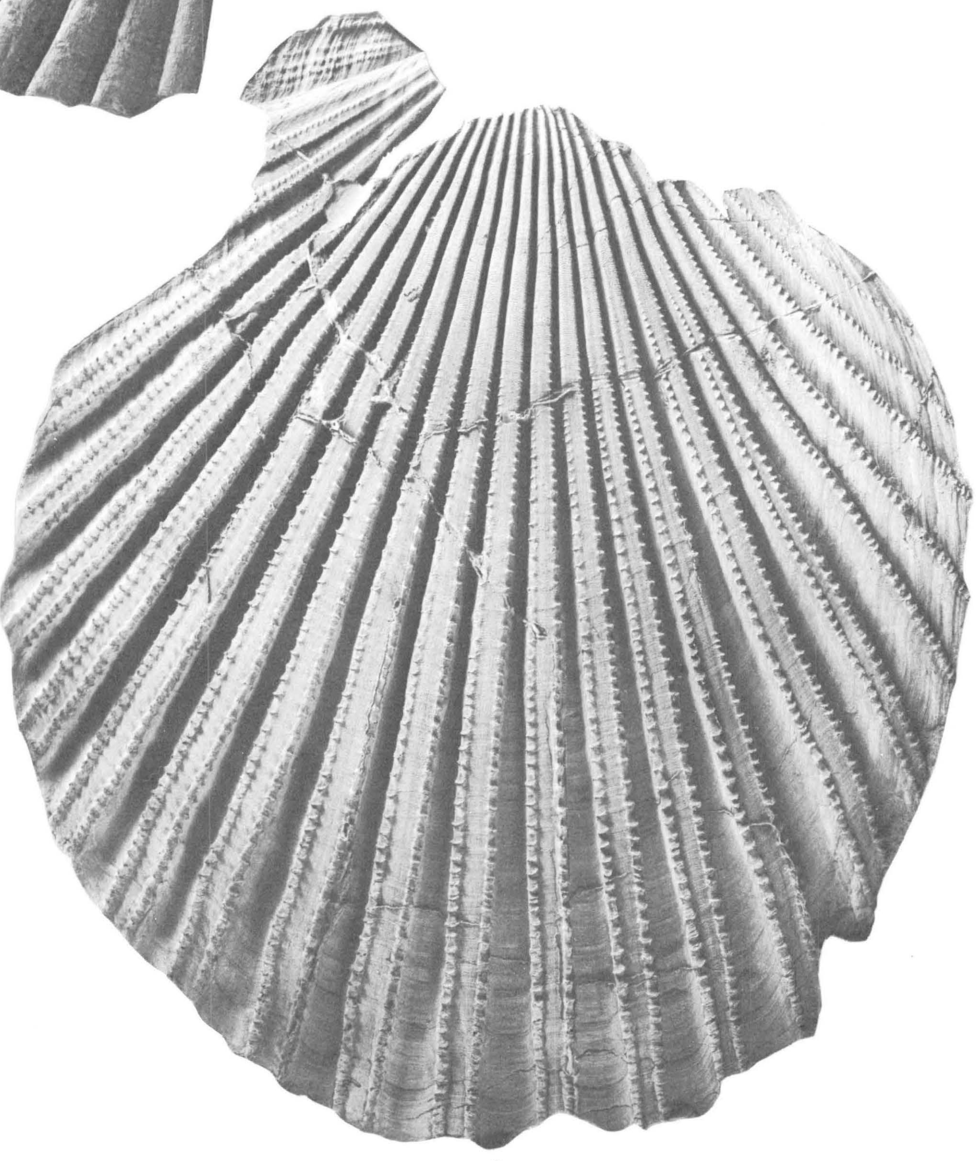


4

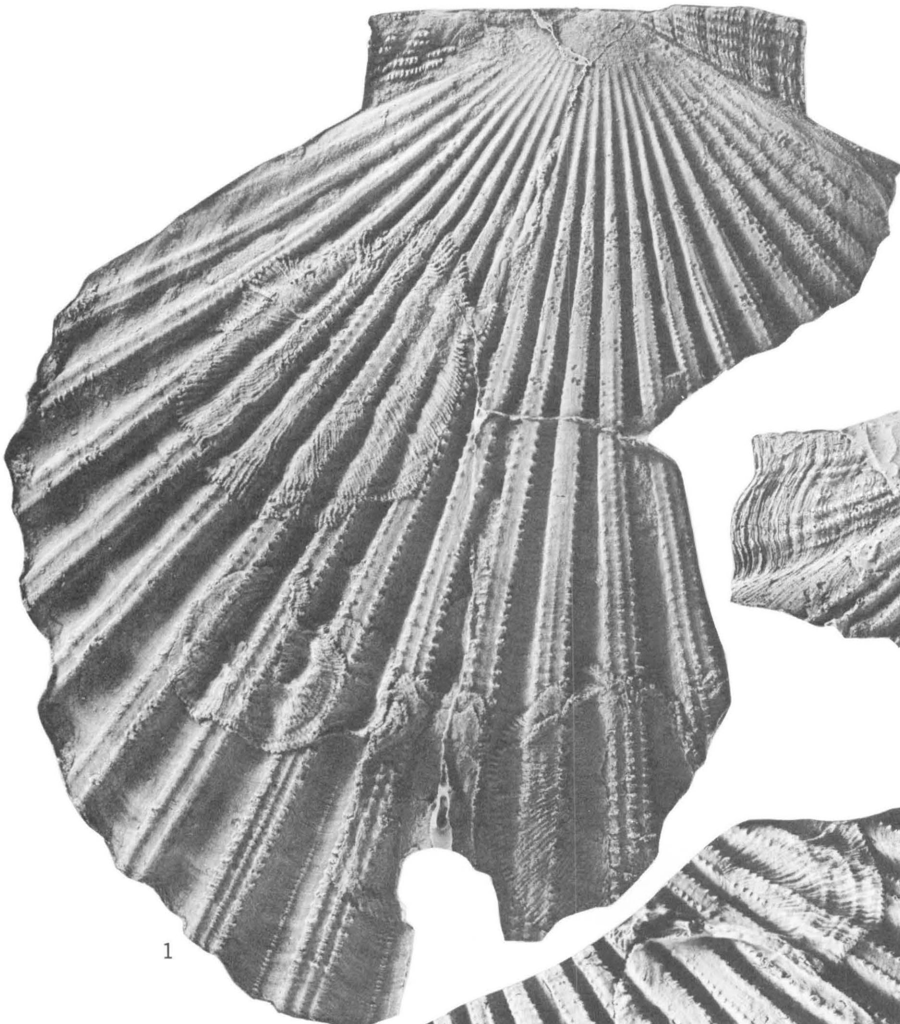
PECTINIDS FROM THE YAKATAGA FORMATION AND THE LOWER SANDSTONE-SILTSTONE AND UPPER MUDSTONE UNITS OF THE UNNAMED UPPER TERTIARY FORMATION IN THE LITUYA DISTRICT

PLATE 43

[All specimens from unnamed upper Tertiary formation, upper mudstone unit, USGS M270]

FIGURES 1–4. *Patinopecten* (*Lituyapecten*) *lituyaensis* MacNeil, n. sp. (p. 231).

1. Incomplete left valve, slightly reduced, USNM 563608, rubber cast, showing three rows of denticles on some ribs and several interspaces with weakly frilled interstitial riblets; note large barnacle bases.
2. Left ear and marginal sculpture of left valve, × 1, USNM 563609, rubber cast.
3. Left-valve fragment, × 1, USNM 563610, rubber cast, showing a well-preserved pair of ears.
4. Lower part of a large left valve, slightly reduced, USNM 563611, rubber cast, possibly stretched laterally; the mold of this specimen was partly destroyed to expose the right valve illustrated on plate 41, figure 1.



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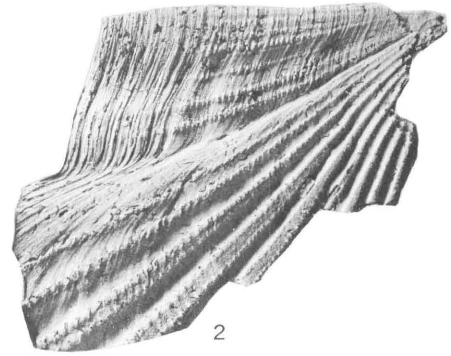

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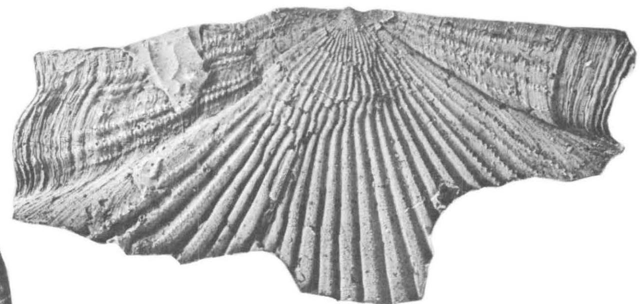

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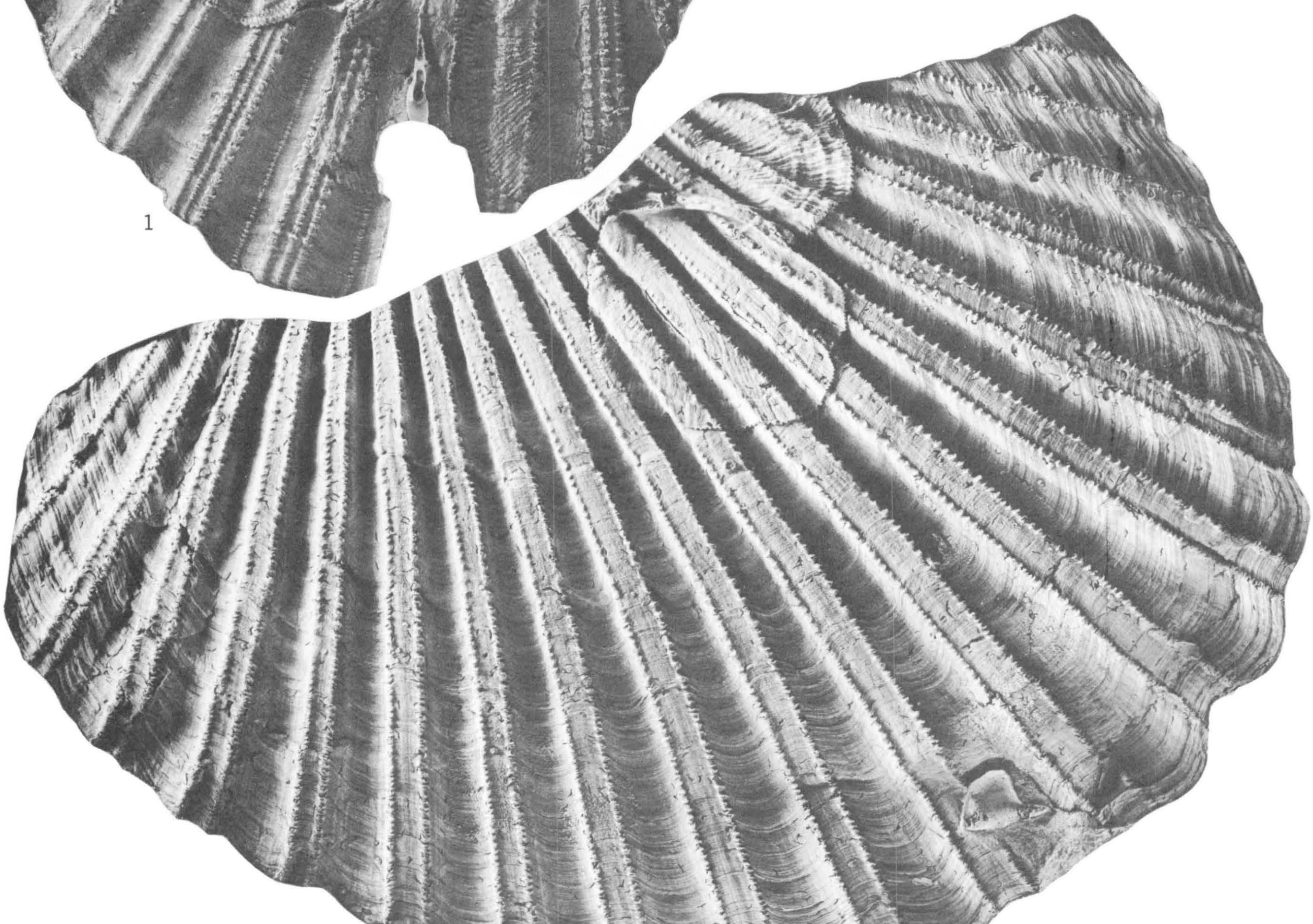


4

PECTINIDS FROM THE UPPER MUDSTONE UNIT OF THE UNNAMED UPPER TERTIARY FORMATION IN THE LITUYA DISTRICT

PLATE 44

FIGURES 1, 3. *Patinopecten* (*Lituyapecten*) *purisimaensis* (Arnold) (p. 233).

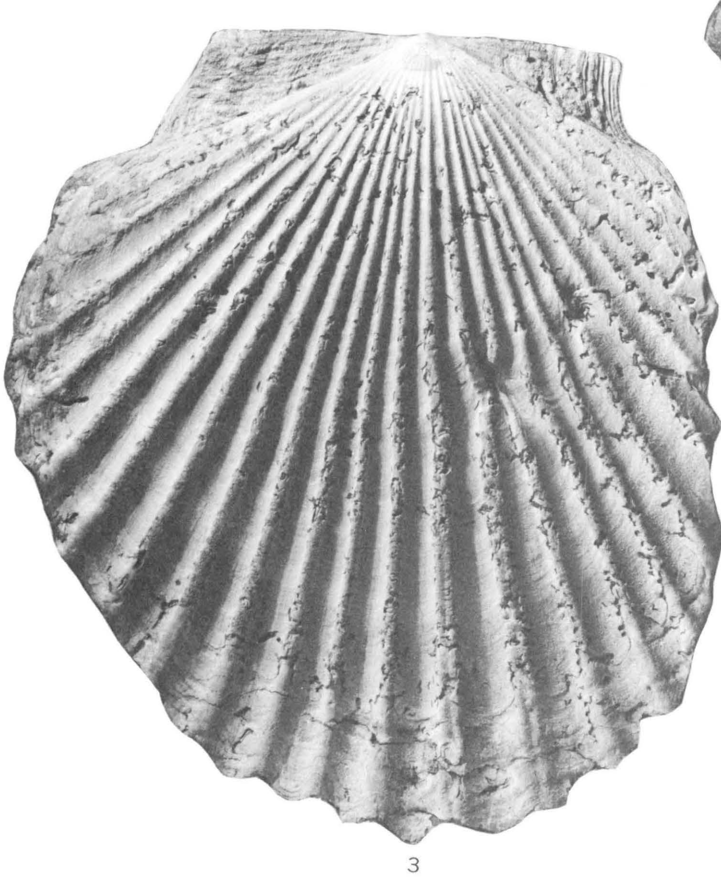
1. Incomplete right valve, slightly reduced, UC 15181, showing marginal denticles or lamellae on ribs; height 123 mm. Purisima formation, UC A-4417.
3. Left valve of same individual, slightly reduced, showing 2 or 3 central ribs with a median sulcus, some juvenile and adult ribs with worn single flanges on their crest.

2, 4. *Patinopecten* (*Lituyapecten*) *falorensis* MacNeil, n. sp. (p. 234).

2. Incomplete right valve, × 1, UC 15977, showing broad adult ribs; height 130 mm. Purisima formation, UC 1788.
4. Fragment of left valve of same individual, × 1, showing broad ribs and marginal denticles; remainder of left valve an internal mold.


1


2


3


4

PECTINIDS FROM THE PURISIMA FORMATION (CALIFORNIA)

PLATE 45

FIGURE 1. *Patinopecten* (*Lituyapecten*) cf. *P.* (*L.*) *dilleri* (Dall) (p. 235).

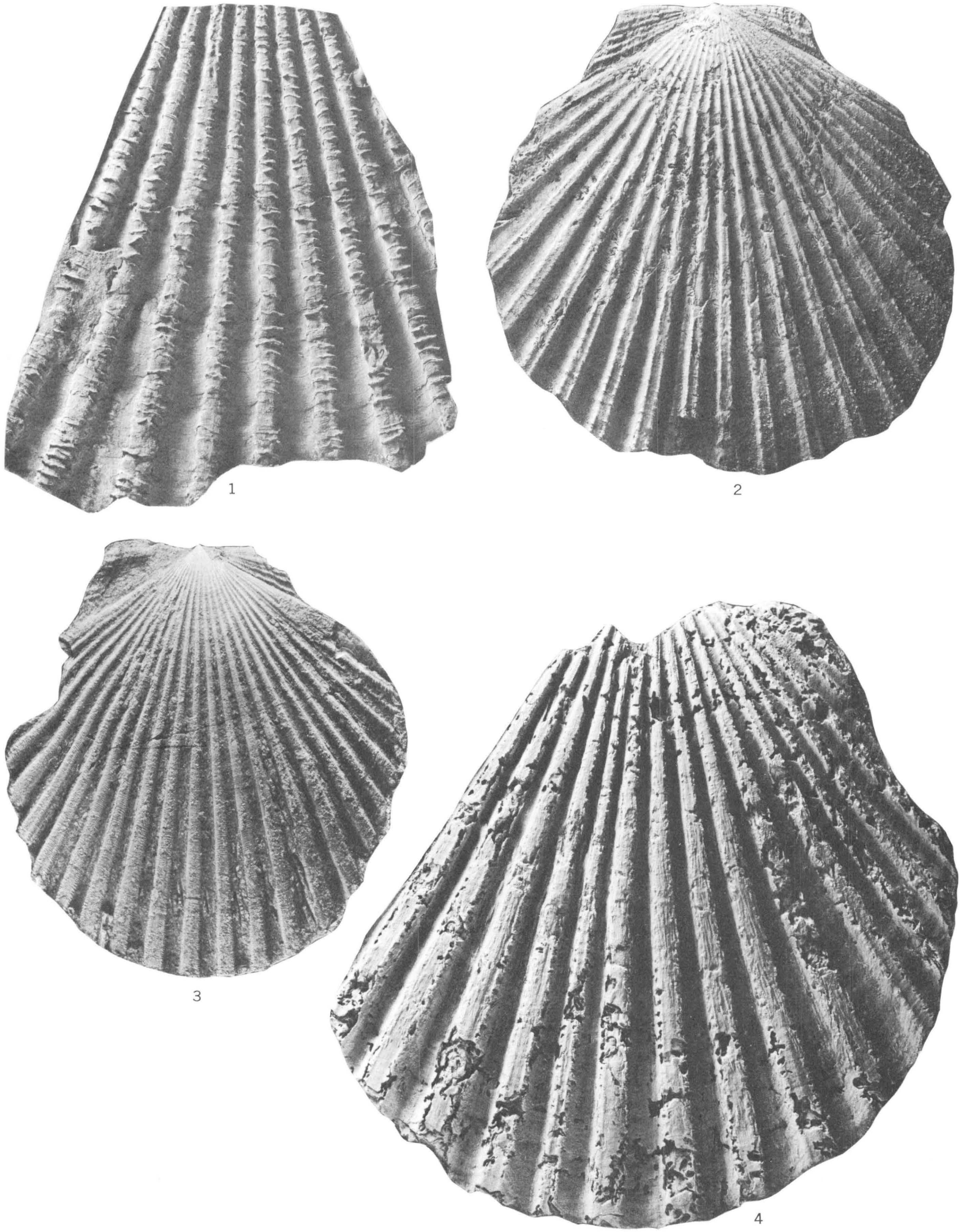
Fragment of a left valve, × 1, USNM 563614, rubber cast, believed to be from the same individual as the right-valve fragments shown on plate 41, figures 4, 5. Unnamed upper Teriary formation, upper mudstone unit, USGS 7931.

2, 4. *Patinopecten* (*Lituyapecten*) *falorensis* MacNeil, n. sp. (p. 234).

2. Left valve of a half-grown specimen, slightly reduced, SU 8690a; height 92 mm; diameter 90 mm; ribs narrower than normal. Purisima formation, Ano Nuevo Point, SU 29788.
4. Partial left valve of a large specimen, slightly reduced, SU 8691; same individual as right valve on plate 46, figure 1. Purisima formation one-fourth of a mile south of San Gregorio, SU 1095.

3. *Patinopecten* (*Lituyapecten*) cf. *P.* (*L.*) *yakatagensis* (Clark) (p. 231).

Left valve of a young specimen, × 1, USNM 563596, showing the juvenile sculpture persisting to a much later stage than normal (see pl. 37, figs. 4, 6, 7); height 90 mm; possibly a subspecies. Uppermost part of Poul Creek formation, USGS 17733.



PECTINIDS FROM THE POUL CREEK FORMATION, THE UPPER MUDSTONE UNIT OF THE UNNAMED UPPER TERTIARY FORMATION IN THE LITUYA DISTRICT, AND FROM THE PURISIMA FORMATION (CALIFORNIA)

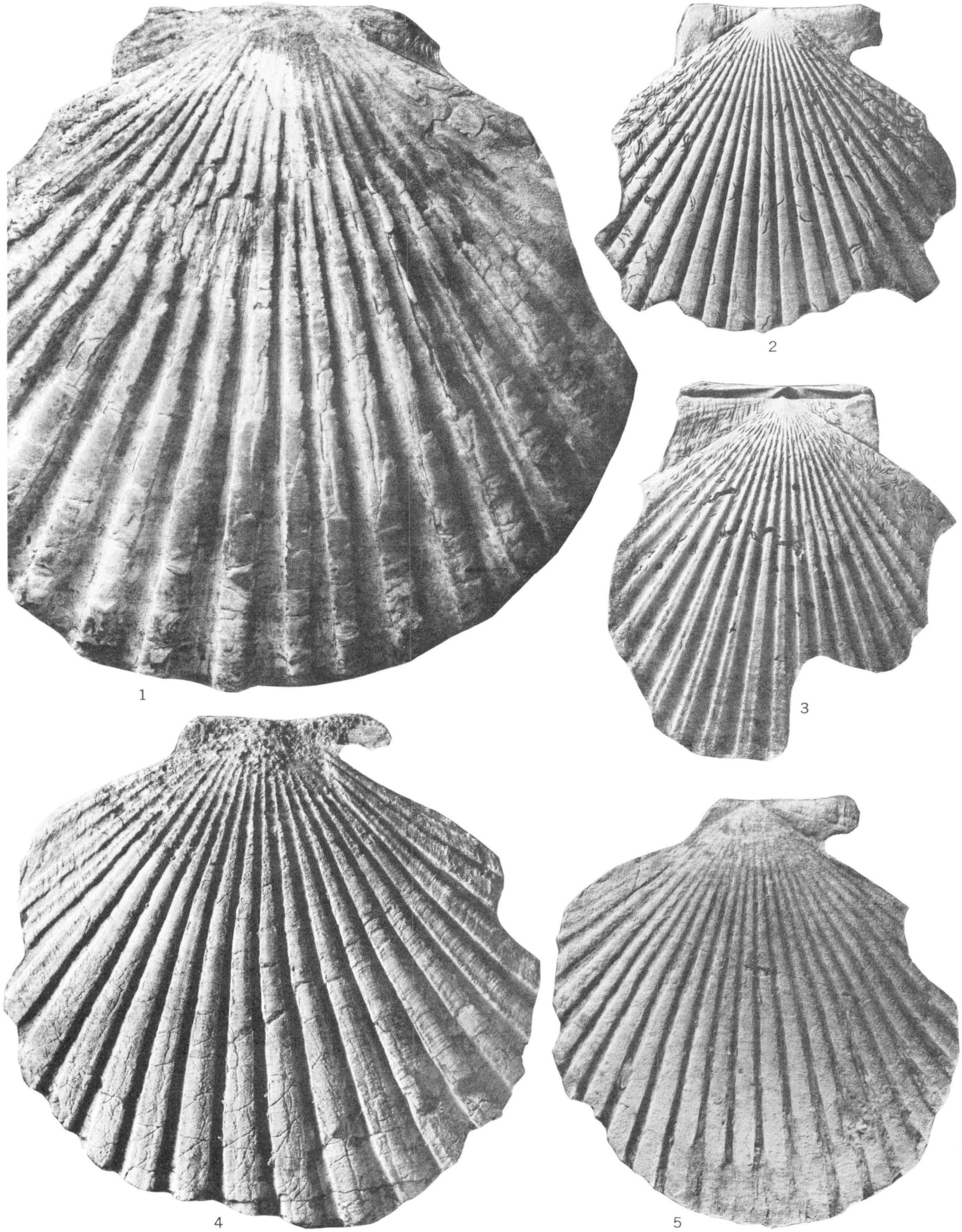
PLATE 46

FIGURES 1–4. *Patinopecten* (*Lituyapecten*) *falorensis* MacNeil, n. sp. (p. 234).

1. Right valve, slightly reduced, SU 8691, narrower ribs than normal and with strong interstitial riblets; height 135 mm; diameter 142 mm; more complete than shown; same individual as plate 45, figure 4. Purisima formation, one-fourth of a mile south of San Gregorio, SU 1095.
2. Part of right valve, × 1, UC 31333, topotype; same individual as figure 3. Falor formation of Manning and Ogle (1950), UC A–4233.
3. Part of left valve, × 1; height 78 mm; diameter 75 mm; same individual as figure 2.
4. Right valve, slightly reduced, SU 8690–b; height 118 mm; diameter 112 mm. Purisima formation, Ano Nuevo Point, SU 29788.

5. *Patinopecten* (*Lituyapecten*) cf. *P.* (*L.*) *yakatagensis* (Clark) (p. 231).

Right valve, × 1, USNM 563597, of the same individual as plate 45, figure 3. Uppermost part of the Poul Creek formation, USGS 17733.



PECTINIDS FROM THE POUL CREEK FORMATION, THE FALOR FORMATION OF MANNING AND OGLE, 1950 (CALIFORNIA), AND THE PURISIMA FORMATION (CALIFORNIA)

Stratigraphic Occurrence of *Lituyapecten* in Alaska

By DON J. MILLER

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 354-K

Detailed discussion of relevant Alaskan formations containing Lituyapecten *and description of collecting localities*

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STRATIGRAPHIC OCCURRENCE OF *LITUYAPECTEN* IN ALASKA

By Don J. Miller

ABSTRACT

The Tertiary beds in the areas where *Lituyapecten* occurs contain three gross units of deposition, the lower, middle, and upper Tertiary units. Although these units indicate a similarity in the succession of the type of sediments received in different geographic districts, they are not supposed to be strictly time divisions. The known occurrence of all types of pectinids in these deposits is stated.

Formations containing *Lituyapecten* are discussed in more detail. These include the Katalla formation in the Katalla district, the Poul Creek and Yakataga formations in the Yakataga district, and an unnamed upper Tertiary formation in the Lituya district.

A generalized correlation chart and a map of the Gulf of Alaska Tertiary province are included; fossil localities are located stratigraphically and geographically on them.

INTRODUCTION

The fossil pectinid pelecypods described in this paper are from rocks of Miocene and Pliocene age exposed in the Katalla, Yakataga, Malaspina, and Lituya districts bordering the northeast shore of the Gulf of Alaska (fig. 47). In this area there is an arcuate lowland and foothills belt that is 300 miles long and 2 to 40 miles wide. The sedimentary rocks of Tertiary age in this belt are exposed or are inferred to underlie lowland areas covered by ice or unconsolidated deposits (Gryc, Miller, and Payne, 1951, p. 159–162). It is of historical interest that the "manteau royal" found in the Lituya district in 1786 by a naturalist in the expedition commanded by the French explorer La Pérouse (1797, p. 189) is the earliest known record of a fossil pecten on the west coast of North America. In compiling the first geologic map of Alaska, Grewingk (1850, p. 99–100, map, pl. 2) cited this shell as evidence for the presence of rocks of Tertiary age on the northeast coast of the Gulf of Alaska.

The sequence of Tertiary rocks exposed in the Gulf of Alaska Tertiary province comprises deposits, mainly clastic, laid down in the Yakataga geosyncline (Payne, 1955) during each of the epochs from Eocene through Pliocene. The known thickness of the sequence at the outcrop exceeds 25,000 feet locally. Significant changes in the environment of deposition during the Tertiary period are reflected in the distinctive lithologic character and organic content in three major divisions of the Tertiary sequence.

The lower Tertiary unit consists of nonmarine, brackish, and marine strata, interbedded and intertonguing and consisting largely of siltstone, arkosic sandstone, and coal. It contains a continental flora and a marine invertebrate fauna of tropical to subtropical aspect. Only one fragmental specimen of a pectinid is known to have been collected from beds assigned to the lower Tertiary unit; it may be a *Patinopecten*.

The lower Tertiary unit includes the Stillwater and Kushtaka formations, the lower part of the Tokun formation in the Katalla district, and an unnamed siltstone and the Kulthieth formation (at the top) in the Yakataga and Malaspina districts.

The middle Tertiary unit consists mainly of marine strata deposited in water of shallow to moderate depth. This unit is characterized by massive poorly sorted or unsorted concretionary siltstone and mudstone and by widespread but generally thin beds of glauconite sandstone and water-laid volcanic breccia or tuff. The marine invertebrate fauna suggests warm, temperate to subtropical waters. Small mud pectens (*Delectopecten* have been collected at several localities from beds in the lower and middle parts of the middle Tertiary unit. At least one species of large pecten, *Patinopecten* (*Lituyapecten*) *poulcreekensis*, occurs in the uppermost part of the middle Tertiary unit, or in beds transitional between the middle and upper Tertiary units.

The middle Tertiary unit includes the upper part of the Tokun formation and lower and middle parts of the Katalla formation in the Katalla district, and the Poul Creek formation in the Yakataga district. Possibly the lowermost part of the unnamed beds constituting the Tertiary sequence in the Lituya district belongs to the same sedimentary regimen as the middle Tertiary unit.

The upper Tertiary unit is wholly marine and consists of sandstone, siltstone and conglomerate deposited in shallow-water, and marine tillite. The tillite, a massive sandy mudstone containing marine fossils and randomly distributed coarse, ice-rafted clastic fragments is interbedded with and grades laterally into the normal marine sedimentary rocks (Miller, 1953a, p. 22–35). The lithologic evidence for supposed glaciation in the Gulf of Alaska region in late Tertiary time is supported by a marine invertebrate fauna that is generally indicative of cool, temperate to boreal water and that includes many species whose closest living relatives are found in the Gulf of Alaska or farther north. Pectinids are a conspicuous and locally abundant element of the marine invertebrate fauna in the upper Tertiary unit.

The upper Tertiary unit includes the upper part of the Katalla formation in the Katalla district, the Yakataga formation in the Yakataga and Malaspina districts, and at least the upper part of the Tertiary sequence in the Lituya district.

The pectinids described in this paper are from the following stratigraphic units: (a) The upper part of the Katalla formation in the Katalla district; (b) the uppermost part of the Poul Creek formation in the Yakataga district; (c) the Yakataga formation in the Yakataga and Malaspina districts; and (d) an unnamed formation of late Tertiary age in the Lituya district. Uncertainties regarding exact correlation of these formations (fig. 46) within the Gulf of Alaska Tertiary province and also within the Oregon and Washington Tertiary section are due mainly to discontinuity of outcrops and lack of detailed field information, to scarcity or poor preservation of fossils in some parts of the formations, to ecological differences between the dominantly cold-water fauna in the Gulf of Alaska region and the more temperate faunas of the Tertiary sections on the Pacific coast farther south, and to the difference of opinion as to the classification of the Pacific-coast Tertiary sections with reference to the international time scale.

THE FORMATIONS

KATALLA FORMATION

Martin (1905, p. 13; 1908, p. 27–37) proposed the name Katalla formation for a section of rocks of Tertiary age exposed in the hills south of Bering Lake in the Katalla district (formerly called the Controller Bay region). Martin was uncertain of the exact age of the Katalla formation and of its stratigraphic position relative to the sequence of Tertiary rocks exposed north of Bering Lake, which he divided, in ascending order, into the Stillwater, Kushtaka, and Tokun formations. More recent detailed field investigation (Miller, Rossman, and Hickcox, 1945; Miller, 1951) including a restudy of the fossils by several paleontologists, indicates that the approximately 8,600 feet of marine strata designated as the Katalla formation by Martin in the type area are Oligocene and Miocene in age, and that the basal unit of interbedded siltstone and sandstone is equivalent to the upper part of the Tokun formation.

The sequence exposed in the isolated outcrop area of the Suckling Hills, in the extreme southeast part of the Katalla district, is equivalent to the middle and upper part of the Katalla formation of Martin in the type area, and may also include some younger beds. Lot 15852, containing a fragment of a large pecten identified as *Patinopecten* (*Lituyapecten*) *poulcreekensis*, was collected from sandstone near the contact of a predominantly sandy unit with the underlying predominnantly silty unit. This contact is tentatively correlated with the contact between the predominantly sandy upper part of the Katalla formation and the predominantly silty middle part in the type area, and with the contact between the Yakataga and Poul Creek formations in the Yakataga district. Another specimen of what may be the same species of pecten (USGS loc. 15843) was found in a loose concretion on the east flank of the Suckling Hills. The predominantly silty sequence exposed at this locality is thought to be equivalent to the middle or even the lower part of the middle silty unit of the Katalla formation, but the concretion may have come from higher in the section.

POUL CREEK FORMATION

The Poul Creek formation of Taliaferro (1932, p. 754–756), as redefined recently (Miller, 1957), includes about 6,100 feet of marine interbedded sandstone and siltstone of Oligocene and early Miocene age. At most localities in the Yakataga district, the contact of the Poul Creek formation with the overlying Yakataga formation is gradational through a stratigraphic interval of 50 to 200 feet in which the typical reddish-brown-weathering silty rocks of the Poul Creek are interbedded with typical gray-weathering sandstone and siltstone of the Yakataga. This change in lithology coincides with a marked change in the marine invertebrate fauna; the characteristic deeper and warmer water fauna of the middle Tertiary unit gives way to the characteristic shallower and colder water fauna of the upper Tertiary unit. The pectens from USGS localities 17733, M271, and CAS 29261 collected on Yakataga Reef, are from a 50-foot-thick transitional unit between

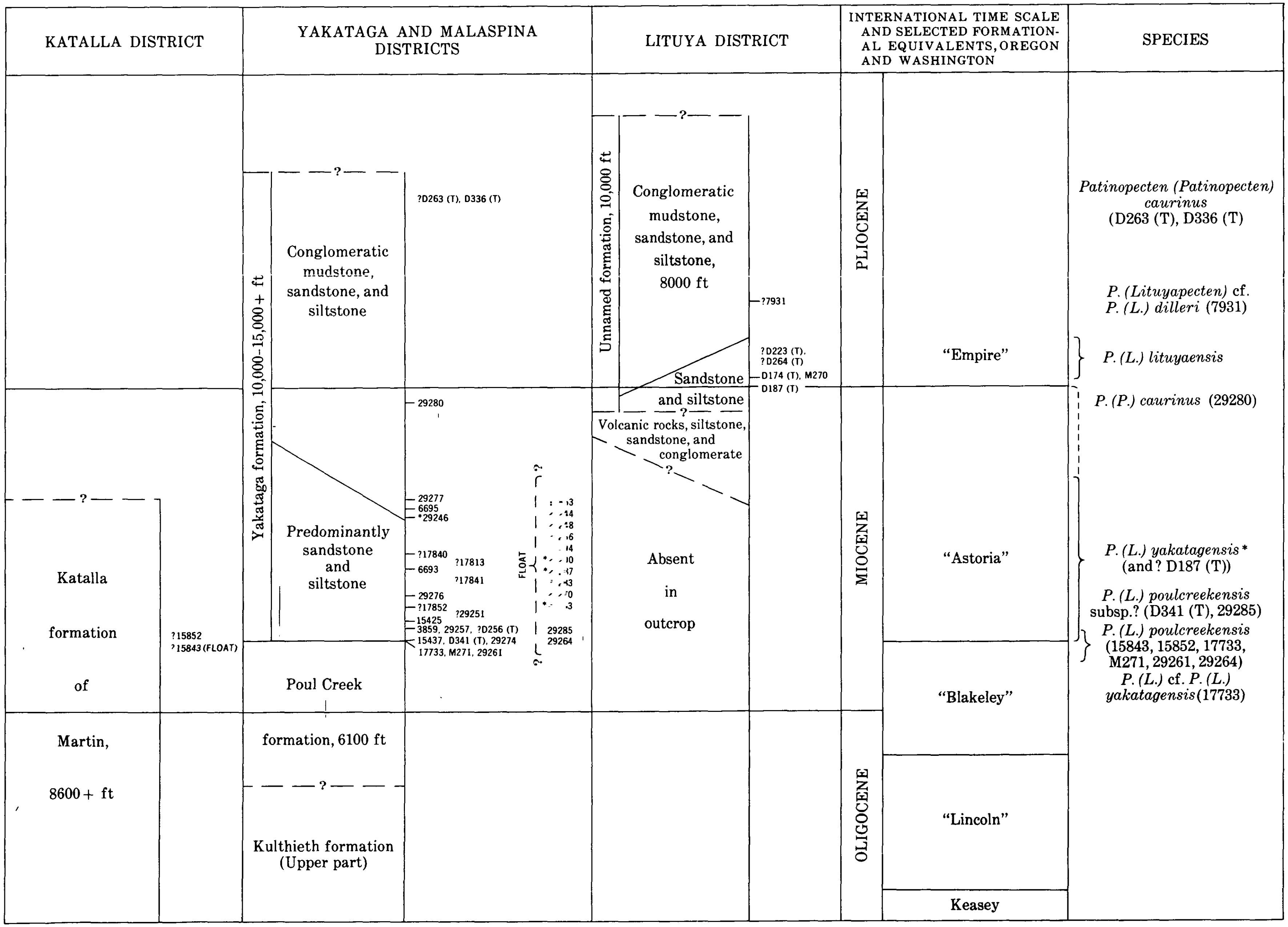

Figure 46. Generalized sections and tentative correlation of middle and upper Tertiary formations in the Gulf of Alaska Tertiary province, showing approximate stratigraphic position of collections containing large pectinid pelecypods.

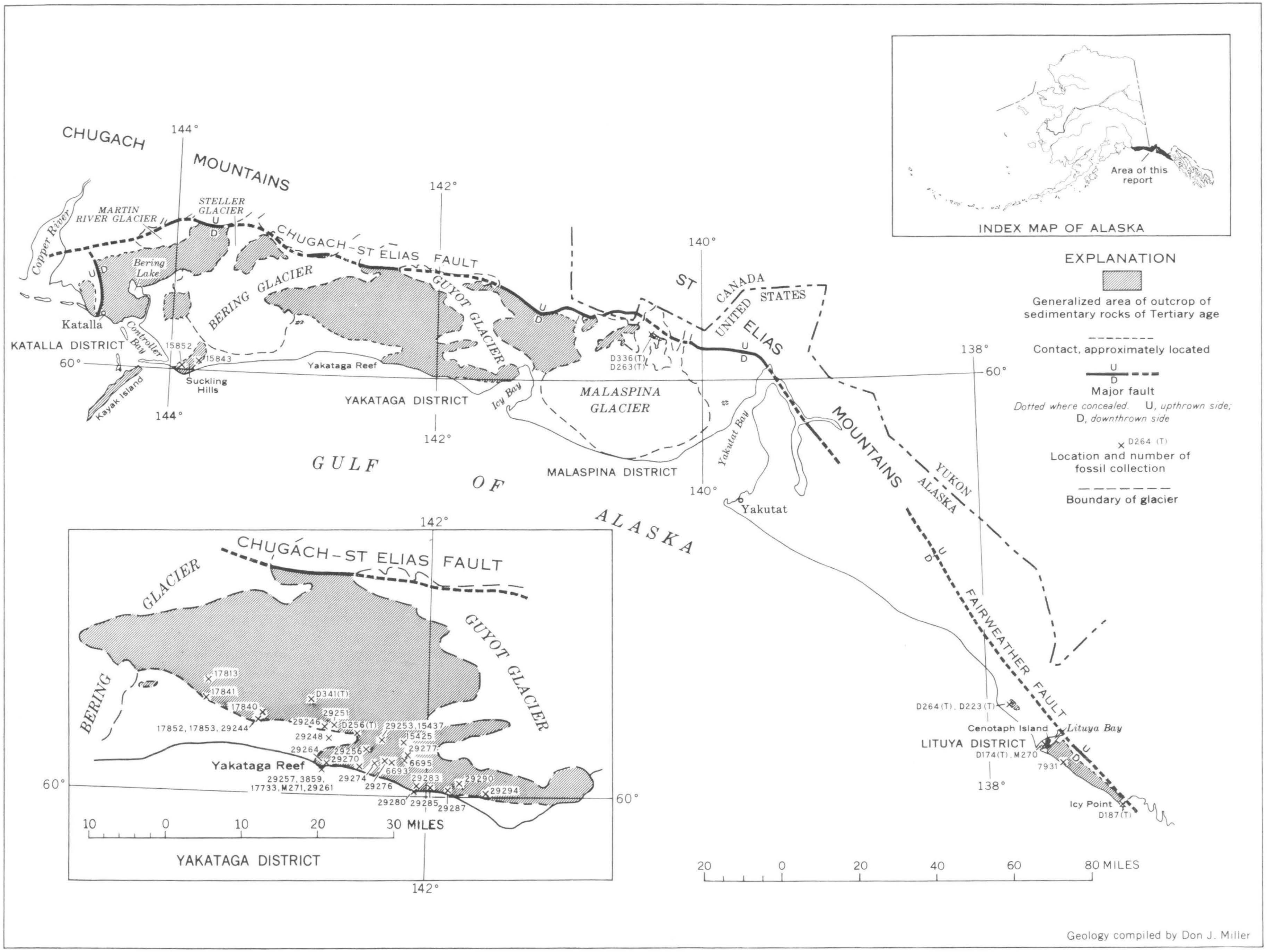

FIGURE 47.—Map of the Gulf of Alaska Tertiary province, showing localities at which large pectinid pelecypods have been collected.

the Poul Creek and Yakataga formations. The contact here was arbitrarily drawn at a more conspicuous change in lithologic character above the pecten-bearing siltstone and silty sandstone. The fragment of pecten in USGS D341 (T) came from similar muddy sandstone in the transitional zone at another locality.

YAKATAGA FORMATION

Taliaferro (1932, p. 756–762) proposed the name Yakataga formation for the younger Tertiary marine strata above the Poul Creek formation in the Yakataga district. Miller (1957) redefined the basal contact of the Yakataga formation in the Yakataga district, and Plafker and Miller (1957) extended the name to include strata in the Malaspina district that were originally named the Pinnacle system by Russel (1891, p. 170–173; 1893, p, 26). As now recognized the Yakataga formation totals a minimum of 10,000 feet, possibly 15,000 feet or even more, of marine sedimentary rocks, chiefly sandstone, siltstone, and conglomeratic sandy mudstone, of Miocene and Pliocene(?) age. In the Yakataga district, interbedded sandstone and siltstone predominate in the lower part of the formation through a section ranging in thickness from 3,500 to at least 5,500 feet; above this section, conglomeratic sandy mudstone is the predominant rock type. In the central and eastern part of the Malaspina district, only the upper part of the Yakataga formation crops out; this part rests with angular unconformity on rocks of early Tertiary age and older.

The most characteristic and abundant pectinid in the Yakataga formation, *Patinopecten* (*Lituyapecten*) *yakatagensis* (Clark), has been found mainly in sandstone beds, but also in siltstone and mudstone in the lower 3,000 to 3,700 feet. Another pectinid, probably *Patinopecten* (*Patinopecten*) *caurinus* (Gould), has been found about 7,000 feet above the base of the formation in the Yakataga district and in the uppermost part of formation in the Malaspina district.

UNNAMED FORMATION IN THE LITUYA DISTRICT

The sequence of rocks of Tertiary age exposed in the Lituya district has been provisionally divided (Miller, 1953b) into four lithologic units as follows: (a) Concretionary marine siltstone with thin interbeds of sandstone that is 1,200 feet to possibly as much as 4,400 feet thick; (b) volcanic rocks, conglomerate, sandstone, and siltstone that are nonmarine and marine and as much as 1,200 feet thick; (c) interbedded sandstone and siltstone that are marine, 600 feet to at least 2,400 feet; (d) marine conglomeratic sandy mudstone interbedded with sandstone and siltstone that is at least 8,000 feet. Units a and b are believed to be at least in part equivalent in age and to grade into each other, as both units at different places rest unconformably on pre-Tertiary rocks and are overlain with apparent conformity by unit c. The upper part of unit c grades laterally into the lower part of unit d. The two units together constitute a formation of late Miocene(?) and Pliocene age. This unnamed formation is lithologically similar to the Yakataga formation, but unit c is probably entirely or at least in large part younger than the interbedded sandstone-siltstone unit that constitutes the lower part of the Yakataga.

One species of an exceptionally large pecten, *Patinopecten* (*Lituyapecten*) *lituyaensis* MacNeil, n. sp., has been collected at two widely separated localities in the Lituya district from near the base of the unnamed Tertiary formation. A specimen doubtfully referred to *P.* (*Lituyapecten*) *yakatagensis* was found at another locality. A fragment of another species of large pecten, *Patinopecten* (*Lituyapecten*) cf. *P.* (*L.*) *dilleri* (Dall), was found higher in the formation at one locality.

LOCALITIES

The available fossils from the Tertiary rocks exposed in the Gulf of Alaska province were collected over a period of nearly 70 years, mainly by geologists engaged in areal mapping and under conditions that allowed neither time nor facilities for collecting and transporting a large number of specimens. As a consequence of these circumstances, as well as the generally poor preservation of the fossils and the hardness of the Tertiary rocks, many of the fossils, particularly the large pectinids, are fragmentary. On the other hand the conspicuous, large pectinids probably were rarely overlooked where any fossils were collected.

The following descriptions of Alaskan localities at which fossil pectinids were collected include the essential part of the original geographic description, followed, where possible or necessary, by supplementary information in parenthesis locating the collection on the most detailed published topographic map available in 1958. The stratigraphic assignments are the writer's. The California localities were compiled by MacNeil.

ALASKA LOCALITIES

Katalla district

USGS Cenozoic loc.

15843. Creek on southeast flank of Suckling Hills, 3.2 miles N. 26° E. of mouth of Kiklukh River, Bering Glacier quadrangle. Collector, D. J. Miller, 1945. Float, Katalla formation.

15852. Creek on northwest flank of Suckling Hills, 3.1 miles N. 48° W. of mouth of Kiklukh River, Bering Glacier quadrangle. Collector, D. J. Miller, 1945. Katalla formation, upper part.

Yakataga district

USGS Cenozoic loc.

6693. Bluff on south bank of White River one-half a mile below foot of [White River] glacier (2.43 miles N. 4° E. of mouth of Fulton Creek, Bering Glacier A–4 quadrangle). Collector, A. G. Maddren, 1913. Yakataga formation, about 1,800 ft above base.

6695. From sandy shale at intake tunnel of the White River Mining Co.'s flume, North Fork of White River (about 4.8 miles N. 87° W. of Munday Peak, Bering Glacier A–3 quadrangle). Collector, A. G. Maddren, 1913. Yakataga formation, about 3,500 ft above base.

15425. North flank and crest of Yakataga Ridge (5.7 miles S. 72° W. of Mount Eberly, Bering Glacier A–3 quadrangle). Collector, M. S. Walton, Jr., 1944. Yakataga formation, about 500 ft above base.

15437. Unnamed creek on north flank of and parallel to Yakataga Ridge (0.3 mile N. 16° E. of peak 2430 near west end of Yakataga Ridge, Bering Glacier A–4 quadrangle). Collector, E. M. Spieker, 1944. Poul Creek formation, near top, and possibly basal part of Yakataga formation.

17733. Yakataga Reef, about 700 ft N. 30° E. of highest rock on the reef (1.53 miles S. 56° E. of mouth of Mink Creek, Bering Glacier A–4 quadrangle; same locality as M271). Collector, D. J. Miller, 1948. Poul Creek formation, upper 50 ft.

17813. Small stream entering Kulthieth River from the east, 2.4 miles N. 53° E. of junction of Kultheith and Kaliakh Rivers, Bering Glacier quadrangle. Collector, D. J. Miller, 1947. Yakataga formation, probably lower part.

17840. South flank of Kulthieth Mountain, 0.7 mile S. 32° E. of peak 3437, Bering Glacier quadrangle. Collector, R. B. Johnson, 1947. Yakataga formation, at least 2,400 ft above base.

17841. Gulch on south face of ridge at Sunshine Point, 2.0 miles S. 53° E. of junction of Kulthieth and Kaliakh Rivers, Bering Glacier quadrangle. Collector, R. B. Johnson, 1947. Yakataga formation, lower part.

17852. Gulch on south flank of Kulthieth Mountain, 0.85 mile S. 17° E. of peak 3437, Bering Glacier quadrangle. Collector, D. J. Miller, 1947. Yakataga formation, at least 900 ft above base.

17853. Gulch on south flank of Kultheith Mountain, between points 0.8 mile S. 34° E. and 1 mile S. 6° W. of peak 3437, Bering Glacier quadrangle. Collector, D. J. Miller, 1947. Float, lower part of Yakataga formation.

D256 (T). Small outcrop at margin of Yakataga Glacier, at head and on south side of North Channel of the Yakataga River, Bering Glacier A–4 quadrangle. Collector, D. L. Rossman, 1953. Yakataga formation.

D341 (T). Ridge at head of Cotton Creek; altitude 3,800 ft., 1.35 miles N. 30° E. of peak 4014 on Duktoth Mountain, Bering Glacier A–4 quadrangle. Collector, J. E. Heppert, Standard Oil Co. of California, 1954. Probably Yakataga formation, near base; may be at top of Poul Creek formation.

Yakataga district—Continued

USGS Cenozoic loc.—Continued

M271. Yakataga Reef, along strike of beds that intersect the shoreline at a point 700 ft N. 30° E. of the highest rock on the reef (1.53 miles S. 56° E. of mouth of Mink Creek, Bering Glacier A–4 quadrangle; same locality as 17733). Collector, D. J. Miller, 1958. Poul Creek formation, 25 to 50 ft below top.

California Univ. (Berkeley) loc.

3859. Yakataga Reef, from a sandstone about 800 ft above lowest reef exposure (about 1.36 miles S. 56° E. of mouth of Mink Creek, Bering Glacier A–4 quadrangle). Collector, N. L. Taliaferro, 1920. Yakataga formation, about 300–350 ft above base.

California Acad. Sci. loc.[1]

29244. West [south] base of Kulthieth Mountain, at mouth of small stream coming from cirquelike hanging valley, 3 to 4 miles west of Duktoth River (about 1 mile S. 6° W. of peak 3437, Kulthieth Mountain, Bearing Glacier quadrangle). Float, Yakataga formation, lower part.

29246. Gray sandy conglomerate exposed on west side of Miller Creek near mouth of small west tributary, about 1½ miles north (upstream) from first outcrop exposed along west side of creek (about 1.4 miles S. 41° W. of peak 3394 at head of Miller Creek, Bering Glacier A–4 quadrangle). Yakataga formation, probably about 3,300 ft. above base.

29248. Yakataga River (Bering Glacier A–4 quadrangle). Float, from Poul Creek formation and probably from Yakataga formation.

29251. East side of Porcupine Creek, 1½ miles upstream [north] from mouth (about 2 miles S. 31° E. of peak 3394 at head of Miller Creek, Bering Glacier A–4 quadrangle). Yakataga formation, lower part.

29253. Lower 1 mile of Opooch Creek above junction with Yakataga Glacier (along unnamed creek on the north flank of and parallel to the west end of Yakataga Ridge, Bering Glacier A–4 quadrangle). Float, from upper part of Poul Creek formation and from the Yakataga formation, probably only the lower part.

29256. Clear Creek (Bering Glacier A–3 and A–4 quadrangles). Float, from Yakataga formation.

29257. Yakataga Reef, from pecten zone just above a pebble conglomerate which projects farther into the sea than any other of the reef beds (about 1.36 miles S. 56° E. of mouth of Mink Creek, Bering Glacier A–4 quadrangle). Yakataga formation, about 350 ft. above base.

29261. Yakataga Reef, from shaly mudstone zone just above massive sandstone (along strike of beds that intersect the shoreline at a point 1.53 miles S. 56° E. of Mink Creek, Bering Glacier A–4 quadrangle. Poul Creek formation, within 30 ft. of top.

[1] All collections by field party representing The Standard Oil Co. of California, The Tidewater Associated Oil Co., and The Union Oil Co. of California, 1938.

Yakataga district—Continued

California Acad. Sci. loc.[1]—Continued

29264. Twomile Creek, below forks (Bering Glacier A-4 quadrangle). Float, from upper part of Poul Creek formation and possibly also from lower part of Yakataga formation. The lithologic character of matrix attached to the large pecten suggests Poul Creek.

29270. Hamilton Creek (Bering Glacier A-4 quadrangle). Float, from upper part of Poul Creek formation and lower part of Yakataga formation.

29274. Outcrop of brown sandstone just above rivers edge on east side of big bend on White River, 1½ to 1¾ miles upstream from the mouth (about 1.85 miles N. 14° E. of mouth of White River, Bering Glacier A-4 quadrangle). Near base of Yakataga formation or near top of Poul Creek formation.

29276. South side of White River across from Three Cabins camp (about 2.55 miles N. 16° W. of mouth of Fulton Creek, Bering Glacier A-4 quadrangle). Yakataga formation, about 1,200 ft. above base.

29277. Nearly horizontal beds in canyon on upper part of White River, about one-quarter of a mile upstream from end of old flume (about 4.6 miles N. 84° W. of Munday Peak, Bering Glacier A-3 quadrangle). Yakataga formation, about 3,700 ft. above base.

29280. Umbrella Reef, from shore outward through an estimated stratigraphic thickness of 500 feet (about 0.3 mile west of mouth of Lawrence Creek, Bering Glacier A-3 quadrangle). Yakataga formation, about 6,000 to 6,500 ft. above base.

29283. Lawrence Creek (Bering Glacier A-3 quadrangle). Float, from lower part of Yakataga formation and upper part of Poul Creek formation.

29285. Poul Creek (Bering Glacier A-3 quadrangle). Float, from upper part of Poul Creek formation and lower part of Yakataga formation.

29287. Munday Creek (Bering Glacier A-3 quadrangle). Float, from upper part of Poul Creek formation and possibly from lower part of Yakataga formation. The lithologic character of matrix attached to the pecten suggests Poul Creek.

29290. Mouth of tributary creek entering Johnston Creek on the east side about one-quarter of a mile upstream from General Petroleum Co. drilling camp (about 3.9 miles S. 34° E. of Munday Peak, Bering Glacier A-3 quadrangle). Float, from all but the lowest part of the Poul Creek formation and probably from the lower part of the Yakataga formation. The lithologic character of matrix attached to the pecten suggests Poul Ceek formation.

29294. Little River (Bering Glacier A-3 quadrangle). Float, upper part of Poul Creek formation and lower part of Yakataga formation.

[1] All collections by field party representing The Standard Oil Co. of California, The Tidewater Associated Oil Co., and The Union Oil Co. of California, 1938.

Malaspina district

USGS Cenozoic loc.

D263 (T). Point Glorious, about 1.68 miles N. 68° W. of peak 5520, Mount St. Elias quadrangle. Collector, George Plafker, 1953. Yakataga formation, upper part.

D336 (T). Point Glorious, probably same locality as D263 (T). Collector, I. C. Russell, 1890.

Lituya district

7931. Sea cliff cut by stream 6½ miles southeast of Lituya Bay, about 500 ft from beach (about 2 miles southeast of mouth of Steelhead Creek, Mount Fairweather quadrangle). Collector, J. B. Mertie, Jr., 1917. Unnamed upper Tertiary formation about 3,200 ft above base; upper mudstone unit.

D174 (T). Southwest shore of Cenotaph Island, 3,500 ft S. 70° W. of easternmost cape of island (Lituya Bay, Mount Fairweather quadrangle). Collector, D. J. Miller, 1952. Unnamed upper Tertiary formation about 1,070 ft above base; upper mudstone unit.

D187 (T). Ocean beach reef, Icy Point measured section, 1.04 miles, S. 22° W. of mouth of Kaknau Creek (Palma Bay, Mount Fairweather quadrangle). Collector, J. F. Seitz, 1952. Unnamed upper Tertiary formation about 800 ft above base; probably lower sandstone-siltstone unit.

D223 (T). Cliff at east margin of glacier at Cape Fairweather, about 3.8 miles N. 80° W. of Mount Escures, Mount Fairweather quadrangle; same locality as D264 (T). Collector, C. E. Kirschner, Standard Oil Co. of California, 1953. Unnamed upper Tertiary formation, probably in lower sandstone-siltstone unit.

D264 (T). Cliff at east margin of glacier at Cape Fairweather, about 3.8 miles N. 80° W. of Mount Escures, Mount Fairweather quadrangle; same locality as D223 (T). Collector, D. J. Miller, 1953. Unnamed upper Tertiary formation, probably in lower sandstone-siltstone unit.

M270. Southwest shore of Cenotaph Island, along strike of beds from a point 0.83 mile N. 84° W. of easternmost cape in the island to a point 0.65 mile S. 70° W. of the same cape; Lituya Bay, Mount Fairweather quadrangle. Collector, D. J. Miller, 1958. Unnamed upper Tertiary formation 1,050 to 1,090 ft above base; upper mudstone unit.

California localities

California Univ. (Berkeley) loc.

1780. In the sea cliffs and small reefs ¼ to ½ mile due west of the mouth of Ano Neuvo Creek, San Mateo County, Calif. B. Martin, collector. No date. Purisima formation, Pliocene.

1788. In the sea cliffs at the mouth of Purisima Creek, San Mateo County, Calif. B. Martin, collector. No date. Purisima formation, Pliocene.

California localities—Continued

California Univ. (Berkeley) loc.—Continued

A–4233. Bank of Boulder Creek from 100 yd south to 200 yd north of bridge near "Beckstine Ranch" (Wiggins Ranch), in about a 20 ft stratigraphic interval, about 10 miles southeast of Blue Lake, Humboldt County, Calif. B. A. Ogle, collector, 1946. Falor formation, Pliocene.

A–4343. Halfway between San Gregorio and Pescadero Lagoon on the coast, San Mateo County, Calif. M. K. Gebert, collector. No date. Purisima formation, Pliocene.

A–4417. North side of San Gregorio Lagoon, San Mateo County, Calif. J. W. Durham, collector, 1948. Purisima formation, Pliocene.

California Univ. (Los Angeles) loc.

8072 (plesiotype No. 309). India and Upas Streets, San Diego, Calif. E. H. Quale, collector, 1931. San Diego formation, Pliocene.

Stanford University catalog No.

1095. San Gregorio beach, one-quarter of a mile south of mouth of San Gregorio Creek, San Mateo County, Calif. Enos Preston, collector, 1907. Purisima formation, Pliocene.

4821. Ford across Eel River halfway between Scotia and Nanning Creek, Humboldt County, Calif. H. Hannibal, collector, 1913. "Wildcat series" of Lawson; probably from the Rio Dell formation of Ogle, Pliocene.

4828. Top of ridge between two legs of trail fork in Dry Canyon, an east branch of Tapo Canyon, 3.8 miles north of Santa Susana, north side of Simi Valley, Santa Susana quadrangle, Ventura County, Calif. George Boulware, collector, 1920. Pliocene.

4837. In Boulder Creek for one-quarter of a mile up and one-quarter of a mile down from Maple Creek post office (Boulder Creek and Maple Creek are in the Blue Lake quadrangle), Humboldt County, Calif. H. Hannibal, collector, 1913. Falor formation, Pliocene.

4922. Ano Nuevo Point, San Mateo County, Calif. R. Arnold, collector, 1903. Purisima formation, Pliocene.

4932. East branch of south fork of Eel River from mouth of Panther Creek up creek for 1 mile, Humboldt County, Calif. W. G. Cooper and H. Hannibal, collectors, 1913. "Wildcat series" of Lawson; probably from the Rio Dell formation of Ogle, Pliocene.

4936. Mouth of large arroyo northwest of Elephant Mesa, Scammon Lagoon quadrangle, Lower California. B. F. Hake, collector, 1921. Pliocene.

4937. Same as 4932.

4942. Yellow sandstone, Casmalia Hills, 2.6 miles N. 50° E. of "BM 95" (BM 95 is located in San Antonio Creek about 4.2 miles south of Casmalia—can be found on pl. 1 in U.S. Geol. Survey Bull. 322), Todos Santos y San Antonio, Santa Barbara County, Calif. C. F. Tolman, collector, 1924. "Pliocene."

29788. Ano Nuevo Point, San Mateo County, Calif. R. Arnold and W. R. Hamilton, collectors, 1903. Purisima formation, Pliocene.

California localities—Continued

California Acad. Sci. Soc.

117. "Wildcat series," Humboldt County, Calif. B. Martin, collector. 1912.

2095. Same as Stanford Univ., 4936.

34391. Tomkins Hill gasfield, secs. 23 to 24, T. 3 N., R. 1 E., Humboldt County, Calif. T. W. Cameron, collector, 1955. "Wildcat Pliocene."

USGS Cenozoic loc.

3363 (USNM 164846). Bluffs opposite Rio Del, Eel River, Humboldt County, Calif. J. S. Diller, collector, 1906. "Wildcat series" of Lawson; lower part of the Rio Dell formation of Ogle, Pliocene.

14649. Graciosa Ridge, 450 ft south-southwest of Union Oil Co. Graciosa 3 well, Orcutt field, Santa Barbara County, Calif. W. P. Woodring, collector, 1939. Cebada fine-grained member of the Careaga sand stone, Pliocene.

USNM catalog No.

560053. 1.8 miles S. 35° E. of Casmalia, Santa Barbara County, Calif. L. M. Clark, collector, no date. Foxen mudstone, Pliocene.

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